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The ADVANCEMENT OF SCIENCE

Vol. X, No. 37

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Resistance to Change
Human Biochemical Genetics
Carboniferous Rocks of N.W. Ireland
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CHEMICAL ENGINEERING IN INDUSTRY

At the Annual Meeting in Belfast, Section G (Engineering) devoted a session on Monday, September 8, 1952, to education and training in chemical engineering. Prof. D. M. Newitt, F.R.S., discussed the place of chemical engineering in higher technological education in the light of the functions of a chemical engineer in industry. Dr. E. H. T. Hoblyn dealt with the national need for chemical engineers, their training and relation to the chemist and to other types of engineers. The discussion which followed the presentation of these two papers was opened by Sir Harold Hartley, K.C.V.O., C.B.E., F.R.S., past president of the British Association and of the Institution of Chemical Engineers. The Association is indebted to *Engineering* for a record of the discussion which is more fully reported in the issue of that journal for October 3, 1952.

The Training of Chemical Engineers

by

Prof. D. M. Newitt, F.R.S.

The rise of chemical engineering as a primary technology is one of the direct consequences of industrial and economic developments which are still taking place. It may be said to owe its origin to the big expansion in the heavy chemical industry and to the simultaneous growth of new industries, resulting from intensive scientific research during the latter half of the nineteenth century. There was at that time a growing conviction that empirical methods of plant design, based largely upon trial and error, could no longer meet the needs for better process control and for higher operating efficiencies and would have to give place to more scientific procedures. George E. Davis, one of the pioneers of chemical engineering, first began to lecture on the subject in 1887, and his well-known *Handbook of Chemical Engineering* was published in 1901. The introductory chapters of this book deserve to be studied by anyone in doubt as to the true functions of a chemical engineer.

The new branch of engineering, however, made slow progress in this country and, as has so often happened, it was left to Germany and America to build up those renowned schools of chemical technology and chemical engineering which, during the inter-war years, gave them such an outstanding lead in the international race for higher industrial productivity. We now have to face the task of recapturing some of the lost ground and, by increasing our facilities for higher technological education and vocational (technical) training, of making available to industry the skilled men required, at all levels, for the purpose.

But, in the interval, the picture has changed and the problem has increased in scope and complexity. Technological, economic and social factors are now so closely interwoven in the structure of the modern state that higher technological education must aim at providing not only for the vocational requirements of the technical specialist but also that wider culture essential to those destined for leadership in industry and commerce. It is in this broader context that the training of chemical engineers should be considered.

Perhaps the best approach to the subject is by way of a statement of objectives based upon the needs of industry and the exigencies of the present economic situation. There is a great deal of evidence to suggest that our industries have, over the course of years, lost the initiative in the development of new processes and products ; and numerous examples might be quoted in which inventions and discoveries made by our scientists have been left for exploitation abroad. The growing practice of paying royalties to our competitors on this count is, in every respect, undesirable ; not only is purchased ' know-how ' always out of date, but the practice

denies to our technologists those opportunities for widening their experience and displaying their skill and initiative which are so necessary if we are to compete on level terms in the world's markets.

To meet this situation requires combined action by industry and the schools. The objective of a chemical engineering training is, in the words of Professor W. K. Lewis, ' The development of the capacity of the student when faced with a new and unfamiliar situation, to handle it with a competence, involving skill, initiative and leadership.' Industry must ensure that, when such men are available, opportunities are offered for the exercise of their talents ; its responsibilities, however, do not end here and reference will be made later to ways by which it may with advantage make a contribution in the educational field itself.

It may be well, at this stage, to dispose of certain misconceptions which exist in regard to the nature and scope of a chemical engineering curriculum. In the first place, it must be recognised that the subject constitutes a distinctive discipline which embraces the whole of that body of applied science utilised in transferring a process from the laboratory stage to large-scale production ; it is, in addition, concerned directly or indirectly with the economics of production and with the social implications of new scientific discoveries. The range of subjects to be covered is, therefore, extensive and any endeavour to insist upon a high degree of proficiency in all the sciences included in the definition would be impracticable. A thorough grounding in the fundamental principles of the physical sciences is essential but attention should, thereafter, be directed towards those special applications which constitute what are now generally known as the unit operations and unit processes of chemical engineering.

It will be clear from these considerations that endeavours to base a first degree course in chemical engineering upon any synthesis of existing courses in chemistry, physics and mechanical engineering are unlikely to be successful. The only feasible compromise is that by which chemical engineering may be taken as a post-graduate subject following upon a first degree in chemistry or mechanical engineering ; this method, however, involves an additional one or two years of study and carries with it no very tangible compensating advantages.

From the educational point of view, one of the important problems common to all categories of technology is the emphasis which should be given to works experience as an integral part of a university training. The purpose of introducing a student to industrial life during his university career is to impress upon him at an early stage that this work has to form part of a complex structure, other component parts of which are labour and management. Up to a point, this can be done by instruction in the principles of industrial management and in the economics of production, but nothing can replace the first hand experience gained by direct contact with men and things.

Two alternative methods have been adopted to this end in this country, the one based upon vacation work and the other upon sandwich courses ; in the former, the student is expected to devote some eight weeks of at least two long vacations to employment in a works ; in the latter, more extended periods of employment are sandwiched between attendance at the university. There is not much to choose between the two and both depend for their success upon the student's being able to identify himself with the routine and life of the works and being given definite duties and responsibilities. In all circumstances, he will pick up something of value from such industrial contacts and, when the courses are carefully planned, the benefit he obtains is important and far-reaching.

In general, first degree courses in chemical engineering extend over three post-intermediate years, the first two of which are devoted to the physical sciences and to certain branches of mechanical engineering and mathematics and the final year to unit operations and processes. It cannot be held that such a short period is sufficient to enable any comprehensive syllabus to be covered in its entirety, and it is particularly important to guard against the dangers of introducing so much detail that the student fails to obtain a broad perspective of his subject. For this reason, an extension of the course to a

fourth year, with all the formal apparatus of lectures, tutorials and examinations, is not altogether desirable. The atmosphere of impending examinations is not conducive to independent thought and inquiry; and, if we wish to foster and develop initiative and enterprise, there must be a period during which the student can, under direction, begin to apply his knowledge. In some respects, this end is attained by one or two post-graduate years devoted to original work. In the case of selected students the time so spent is undoubtedly of great value. The planning of a systematic piece of research, the devising of new experimental methods and techniques, the critical appraisal and discussion of results bring out qualities in a student which no system of examinations can hope to reveal. But it must be recognised that all students are not temperamentally or intellectually fitted for research work and no useful purpose is served by forcing them to spend one or two years in a distasteful occupation.

If we remember, however, that the technologies aim at the application of fundamental principles to practical problems and at the introduction of new methods and techniques into industrial practice, it becomes possible to devise a post-graduate course which will entail investigations of a more practical character than those generally included under the heading of fundamental research.

There is no reason why such investigations should not, in suitable circumstances, be undertaken by teams of students rather than by individuals and in co-operation with industry rather than in the isolation of a university laboratory. This matter has been referred to indirectly in the Cremer Report on Chemical Engineering Research, which emphasises the importance of the functional analytical approach to chemical engineering research.

As the result of such a system of training, the graduate should enter industry with a background of fundamental science, with some knowledge of industrial organisation and with a sound understanding of the basic operations of chemical engineering. He will not be familiar with the practice of any one industry nor with those technical details of plant operation which can only be acquired by works experience; and it must be recognised that some time will elapse before he can be expected to make his full contribution as a technical specialist. He should, however, be competent, at the outset, to undertake design and development work and to bring to it those qualities of initiative, originality and adaptability which are so urgently needed in industry to-day.

Finally, it will be evident that chemical engineering differs essentially from those technologies which are confined to the principles and practices of particular industries or of groups of related industries and that chemical engineers can, by the generality of their training, be regarded as a mobile force of technologists able to move from industry to industry as economic conditions dictate.

The Chemical Engineer in Industry

by

Dr. E. H. T. Hoblyn

In any discussion on higher technological education it is necessary to consider, among others, two factors—the part which the technologist is to play in industry and the contribution which industry must make to his training. This paper is devoted to these factors in so far as they concern the education and training of a chemical engineer. The growth of the chemical industry in Great Britain, in the United States, in Germany and elsewhere has brought with it the realisation that chemical engineering is no haphazard admixture of chemistry and engineering, but a distinct technology in its own right —that it has, in fact, emerged as the fourth primary technology. Although comparatively young, the chemical engineer to-day stands shoulder to shoulder with the civil, mechanical and electrical engineer in contributing to the growth of the world's technological industries.

During and since the war there has been a rapidly growing awareness of the lack of technologists in the United Kingdom. This shortage has resulted in others, notably the Americans, developing on a commercial scale the discoveries of our pure scientists, and as Sir Harold Hartley pointed out in his recent presidential address (1) to the Institution of Chemical

Engineers, 'know-how' and designs in certain fields have had to be obtained from abroad. This was not because of any shortcomings in our native skill and ingenuity, but because there were not available the appropriately trained men in sufficient numbers to enable us to do the development work ourselves with the necessary speed. As was pointed out in the Dunsheath Report (2), many Americans believe that their large numbers of chemical engineers have been an important factor in the rapid progress of industry in the United States. In 1949–50, the number of first degrees in chemical engineering in the United States was 4,529, to which must be added 712 Master's and 178 Doctor's degrees. It is doubtful if the United Kingdom's output of chemical engineers from graduate and post-graduate courses will exceed 250 in 1953. Dr. Dunsheath's team was impressed by the importance attached to chemical engineering in America and reported that this is a field to which American industry looks for a large and increasing number of its graduates.

It is not too soon, therefore, that so much attention is now being focused on chemical engineering education in Britain. Before the end of the war, industry was active in putting forward its views on this subject and was instrumental, with the very ready co-operation of the Ministry of Labour and National Service and the Ministry of Education, in establishing soon after the war short-term courses in chemical engineering to bridge the gap until more men were available from the normal university courses. These courses proved most valuable; they not only produced good men but many of them have since grown into full-time degree courses.

The Work of the Chemical Engineer.—Before discussing the part which industry must play in the training and utilisation of chemical engineers it is desirable briefly to examine the main types of work in which they find employment in the chemical and allied industries, including the gas and oil industries. These are research, development and design of plant, construction and installation of plant, process control and plant operation, and plant maintenance. The nature of the work, the type of man employed and the level of qualification required all vary from job to job and from section to section of the industry.

Chemical plant manufacturers use chemical engineers for research and for designing and installing plant and handing it over to the customer operating satisfactorily. Such work is fundamentally the same whether the plant is to be used in the chemical, gas or oil industries and requires to be carried out by fully qualified chemical engineers of high technical ability and preferably having had some plant-operating experience. The plant manufacturer also employs chemical engineers on his sales staff.

The chemical and allied industries employ chemical engineers in two very different spheres which require different levels of educational attainment in the subject. In the first place, the chemical industry uses chemical engineers for research and development and the subsequent design and installation of plant for its own particular processes. This often involves the linking up of specialist equipment supplied by a number of plant manufacturers. Such work may also include the costing of the plant and process and its comparison on technical and commercial grounds with an alternative process. A fully qualified chemical engineer is required for such duties and he must be competent to work closely from the outset of the project, on the one hand with the chemist who has evolved the process in the laboratory and on the other with the civil, mechanical and electrical engineers who will be concerned with the erection and servicing of the plant and the structures which support it or the building which houses it. The chemical industry also employs chemical engineers for plant operation and process control. While large numbers are employed in this way, the number could, with advantage to productive efficiency, be greatly increased, if men with the right type of training were available in sufficient numbers; a lower level of training can normally be accepted for such work, for which Higher National Certificate chemical engineers, to whom reference is made later, should be admirably suited. The oil industry and the gas industry, like the chemical industry,

use chemical engineers for design and development work and for process control and technical supervision. It is clear, therefore, that in the chemical and allied process industries and in the engineering industries which serve them, there is tremendous scope for chemical engineers of varying levels of competence and inclination. What, then, does industry require in their training ?

The Education of the Chemical Engineer.—There has always been a close and mutually valuable relation between British industry and the universities ; as a result, courses in chemical engineering, as in many other subjects, are usually a sound blend of the ideas of academy and industry. Opinions on the method of training a chemical engineer will obviously differ as they do in the case of the training of any other technologist. There is little doubt, however, that the four-year undergraduate course to an honours degree is now accepted as the most usual form of training for a top-grade chemical engineer. It is important to stress that the chemistry and engineering content of the courses leading up to the study in the final year of chemical engineering proper should always be planned with that end in view. Chemistry and engineering must be taught for chemical engineering and there must be no stuffing of the student with facts at the expense of fundamental principles. For example, there is no need for the student to be familiar with a wide range of complex organic syntheses but he should have a clear understanding of the functions of oxidation, reduction, esterification, saponification, and so on, in organic chemical processes, and of the wide applications of reactions such as the Friedel-Craft and the Grignard and the conditions under which they have to be carried out. Similarly, his engineering training should be directed towards a clear understanding of such questions as the flow of fluids, the transfer of heat, the strength of materials and its application to vessel design rather than towards, for instance, a study of mechanisms. It is to be hoped that eventually more of the early training will be given in the chemical-engineering departments themselves.

Courses vary from college to college, and it is desirable that they should, and that each college should build up its own tradition for producing a man with a certain type of training. Depending upon the nature of the work for which the new entrant to industry is required, so should the prospective employer be able to lean towards the products of a particular school of chemical engineering.

Originally, chemical engineering was taught as a post-graduate subject to graduates in chemistry, physics or engineering. Such courses still and must exist for the benefit of those who at a later stage in their academic careers decide to study chemical engineering rather than to proceed to research work in their subject of graduation.

The most significant advance which has been made recently in the scope of chemical-engineering training is the establishment of Higher National Certificates in the subject ; the courses to the H.N.C. will be taken by students holding a National Certificate in chemistry or engineering. Industry should welcome these new courses, which will produce what have already been described as the N.C.O.s of the chemical and chemical-plant industries. It is for industry to ensure that sufficient raw material is forthcoming from its ranks to warrant the establishment of H.N.C. courses in various centres. It must also ensure that it uses these N.C.O.s properly ; first, they should be employed at a level of work suited to their training—in some cases this should enable better qualified men to be released for more responsible duties, while in others it should enable more chemical engineers to be used on duties for which at present they are sadly lacking, such as plant and process control, as mentioned earlier. Secondly, industry must provide the N.C.O. with the incentive of promotion, where competent, to commissioned rank. Care must be taken by those concerned that H.N.C. chemical engineering courses are not established in centres which are so close together that they compete for students. It is far better, initially, to have fewer courses and for those courses to be good and supported by properly equipped laboratories.

Industry's Part in Education.—One of the comments made by witnesses to the Chemical Engineers' Sub-Committee of

the Hankey Technical Personnel Committee was that ' Chemical engineering is essentially an applied science. . . . The object of a university training should not be to turn out a ready-made chemical engineer, but to teach a man to think along the right lines so that after practical experience he can become one '(3). Industry, therefore, must make its contribution to the education of the chemical engineer by being prepared to train him further after he leaves the university. In this connection the graduate must come to industry in the proper frame of mind and there is an onus on the teaching staffs to ensure that students do not leave the universities feeling that they are a heaven-sent gift to industry. Some firms in the chemical-plant field and elsewhere have developed two-year trainee courses for chemical engineering graduates which not only give the men extended training while employed, but also enable the employer to determine the type of work for which a given individual is best suited. At the end of these courses, the trainees are free to go elsewhere should they so desire.

In addition, industry must help the student while he is still at the university by providing facilities for vacation and sandwich courses. There is, understandably, a school of thought which prefers the student to do something totally different during his long vacation, but most students prefer to obtain practical experience at some time during this period. Many firms now have excellent vacation training schemes from which the student can gain real benefit. It is imperative that firms accepting students for vacation work should do so with a full sense of their responsibility in assisting in their training and that close liaison is maintained between the firms and the students' professor. Examples of the type of work on which students can be employed are operational tests on plant or the carrying out of pilot-scale work in connection with some research problem.

There is also good reason to devote one vacation to working on the shop floor. This does not mean that the student should spend hours learning to file flat or to operate some machine tool. He can, however, work on the assembly of plant in the shops, learning from this good and bad features of design ; he can gain some knowledge of the foundry and its problems by working as a mate to a good moulder ; physical operation of a plant which does not readily lend itself to modern methods of automatic control will provide an experience the value of which cannot be lost. There is also a vitally important human aspect of this type of vacation work—it brings the student right alongside the workman ; he learns something of his outlook on life, how he thinks, how he works out problems and above all he learns how to get on with him. Many first-class technical men have failed in plant work because they possessed the unhappy knack of upsetting workpeople.

Works experience can also be obtained by sandwich courses which can be developed into something of real value to industry as well as to the student. The report of the Cremer Committee on Chemical Engineering Research pointed out the need to collect and analyse data from large-scale plant operation. Work of this nature could be carried out by a team of students working under appropriate guidance. There have already been cases in which students on vacation courses have carried out tests on plant, and the data they have collected has led to modifications resulting in greater efficiency of the plant. Investigations on the actual working plant planned jointly by the teaching staff at the university and the technical staff of the company concerned and carried out under supervision during the students' actual course should be developed on an increasing scale in this country. This use of industry as the chemical-engineering laboratory has met with great success at the Massachusetts Institute of Technology, and there is no reason why it should not do so in this country.

Another and totally different aspect of the contribution which industry must make to the training of the chemical engineer concerns particularly the man working for the Higher National Certificate or other external qualification. First, he must be so stimulated that he wants to become a chemical engineer. Then, once he has embarked on this course, those responsible for his work must take an active interest in his studies and by precept

and practice indoctrinate him with their own trained methods of working. For such a man, industry is his only university and therefore his boss must try to be his professor.

The Future.—The report of the Chemical Engineers' Sub-Committee of the Hankey Technical Personnel Committee, published in 1950, gave estimates of the future demand for chemical engineers, but, in view of the expansion of Britain's technological industries and the ever-growing appreciation of the part which the chemical engineer can play in industry, these estimates may well prove to be low. In his presidential address to the Chemistry Section, Professor Wardlaw referred to the changing structure of British industry and the increasingly important part which is being played by the chemical industry. This will undoubtedly continue and it is therefore imperative that further investment be made in chemical engineering education, for it will undoubtedly pay high dividends. Facilities for chemical-engineering training in this country should therefore expand rapidly over the next few years, but at the same time there must be no relaxation of teaching or qualifying standards. In this respect, it is fortunate that the Institution of Chemical Engineers has such a keen sense of its responsibility for maintaining the high standard so properly demanded by the profession.

Discussion

The discussion was opened by Sir Harold Hartley, K.C.V.O., C.B.E., F.R.S., who said the authors of the papers had dealt with the subject on very broad lines from the point of view of the future place of chemical engineering in industry, the composition of chemical engineering and the part industry should play. He did not think, however, that they had been sufficiently provocative in view of the very urgent problems which the country had to face. He asked why it was that the big construction companies in New York could point with satisfaction to the designs they were making for great plants to be erected in this country and in the Dominions. Both authors had claimed that chemical engineering was the fourth primary technology and would like to think that was accepted by other engineers. Historically, it was quite simple: first, there had been civil engineering, which had claimed the whole field; then, from the introduction of the steam engine, the specialised techniques of the mechanical engineers had developed; and the same process had happened again in the case of the electrical engineers. Now, in the twentieth century, with the great development of the chemical industry and the invasion of all processing industries by chemical techniques, this fourth primary technology had been developed.

Sir Harold then read a summarised statement by Professor Elgin, of Princeton, as follows: 'There has developed a distinct body of science which is fundamental and peculiar to chemical engineering. This involves principles, theories, procedures and techniques fundamental to the majority of chemical engineering operations. While, in some cases, this body of science involves and utilises subject matter and principles common to other sciences, it modifies, extends, orients and combines those principles in a unique manner.'

That, Sir Harold said, gave very briefly the general groundwork of chemical engineering. The authors had spoken of the spheres of operations of chemical engineering (research, the design and construction of plant and its operation); but he did not think they had emphasised that chemical engineering was not self-sufficient. The big chemical construction companies had their civil, mechanical and electrical engineers, but it was the chemical engineer who was the co-ordinator of those activities. There was, perhaps, an idea that this was all chemistry. When the chemical engineer took the ideas and the basic research from the laboratory, the design, as in other engineering, was based mainly on classical physics. There was a danger that chemical engineering, like other branches of engineering, was faced with the fact that, with the lure of nuclear physics and electronics, the classical physicist was becoming extinct. In America, a professor of chemical engineering had said that 'the classical physicist is going out of business, and we have to take over.'

Sir Harold said that if he were asked for an example of what the chemical engineer had achieved recently he might take the 'fluidisation' processes, which depended on contact between gases and solids; where, in the old days, gases were passed over fixed solids, nowadays, with an enormous increase of efficiency, those processes were carried out by airborne particles in the gas stream. That development was due entirely to a week-end party of chemical engineers; one of them put up a pilot plant in a very few weeks, and a full-scale plant was erected within a year. That was the kind of approach that the chemical engineer had to these problems.

Speaking of the leeway that had to be made up in this country to satisfy the demands, he said that in the United States 5,000 chemical engineers were being produced in a year, whereas we were producing about 200. That presented a very serious position for industry to face because, as Professor Newitt had pointed out, the importance of chemical engineering as a technology was the generality of the approach of the chemical engineer and his adaptability. Going around the universities, Sir Harold had found a very wide diversity in the methods of training. In America he had found in the engineering faculties a division devoted entirely to chemical engineering, and the training or education there was given almost entirely by teachers of chemical engineering. He felt that in that way perhaps the maximum of efficiency was obtained for the large amount of ground that had to be covered. As a general rule in this country, chemical engineering was combined with the chemical, engineering and physics training in the universities, using these courses as a preliminary to the final year of chemical engineering proper. This had the advantage of bringing chemical engineers into touch with their colleagues, but it meant that they spent a certain amount of time on things not absolutely essential to them. Then there was the extreme case at Cambridge, where students took the first part of the tripos in either chemistry, physics or engineering, and the second part in chemical engineering. Thus there was a wide diversity of educational methods, and every university must follow the practice best suited to its conditions. Sir Harold said he thought that chemical engineering should be a part of the engineering faculty; it was engineering, and that was where it belonged. In some universities there was still what he regarded as an extinct subject for universities, namely, chemical technology, which had its place 50 years ago, but was no substitute for chemical engineering. Chemical technology too often depended on local needs—fats and oils, fuel, textiles, and so on. This tended to produce men with a somewhat specialised type of experience and a rather limited outlook. Referring to the fact that Queen's University, Belfast, was at present laying the foundations for new schools of engineering and chemistry, Sir Harold expressed the hope that in those schools a place would be found for chemical engineering.

Sir Harold concluded with an appeal to engineers to recognise and to give their support to this fourth primary technology.

Mr. C. C. Inglis said he considered it vital to educate students in fundamental principles; but it was also most important to educate them to recognise these principles when they cropped up; often he found that highly educated men failed to do so. He thought that less than a year in a works rarely gave a student time to appreciate the practical side, and for this reason he favoured the sandwich system—a year at the university and another at the works—over five years.

Mr. H. Young agreed that the business of the chemical engineer was primarily one of engineering and a young man should, therefore, begin with a sound basis of shop practice. He pleaded for the encouragement of a system by which it would be worth a student's while to put in at least two years on the shop floor, followed eventually by at least one year in the drawing office.

Mr. J. Taylor, dealing with the problem of providing chemical engineers in sufficient numbers in a fairly short space of time, said the most rapid progress would be made in Britain by providing a post-graduate course, such as the M.Sc., in chemical engineering practice at the M.I.T. Most people in the chemical industry believed in the pure-science degree course as first training, and he

thought that, on the whole, honours graduates in chemistry or physics were preferred, to train as chemical engineers later.

Dr. E. R. Thomas, O.B.E., expressed the hope that as the Higher National Certificate in chemical engineering developed, it would be possible for the better students to enter a university. That was being done in mechanical engineering in one university, and recently he had been meeting the products ; they were a very fine type and should not remain in the 'N.C.O.' category.

Mr. Kenneth R. Evans, whose firm, Messrs. Metropolitan - Vickers, engage about 120 graduates in electrical and mechanical engineering and in other sciences each year, supported Dr. Hoblyn's point that those with a H.N.C. (the N.C.O.s) should have an opportunity to become 'commissioned,' for he felt it would be very bad for the world and for industry if the higher positions became a 'closed shop' for university graduates.

Dr. Hoblyn said that a matter which had become very confused was the difference between training and education. The references to having university courses upset by lengthy spells in industry, and to young men, having advanced in their school work to, say, university entrance standard, going into industry for two or three years before going up to the university, seemed to have produced a rather confused state of mind. Commenting on the question of whether some chemical engineering study superimposed on, say, chemistry was better than a direct four-year course, he urged that both should be available and it should be made possible for any chemist who wanted to become a chemical engineer to train for that purpose.

Professor Newitt said he was glad to find that so much attention had been given to the relations between the schools and industry, for that was the crux of the whole matter. On the whole, he thought the easiest way from the teacher's point of view was that a young man should go from school to university, recognising that when he left the university he still needed training. His misgiving regarding sandwich courses concerned the machinery for linking up the training in industry with the university training. He was sorry that Mr. Taylor had again put forward his view that the right way in which to train a chemical engineer was for him to take a first degree in chemistry and then to have something superimposed upon it.

Although he had great sympathy with the scheme for establishing practice schools, he thought that the machinery for getting them going would be rather difficult to organise. During the first two or three years, the students became obsessed with examinations, and they had not time to think about the recognition of first principles. That was why it was so important, after the examinations were over, to provide a post-graduate period during which that second part of a man's training could be given emphasis. That was his solution of the problem.

Sir Ben Lockspeiser, K.C.B., F.R.S., said it would be extremely useful if the young people who felt strongly about the matter could discuss it round a table. The meeting had carried the discussion of the subject a useful step forward, and by the expression of views round a table something further might be achieved.

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SEISMIC REFRACTION SHOOTING IN THE DEEP SEA[1]

by

DR. M. N. HILL

The Fundamental Problem of Deep Sea Structure

THE layering of the continental surface is, broadly speaking, known. This knowledge comes from a variety of sources of which the most important is the direct study by geologists of the surface features and rocks. This source is restricted to comparatively shallow depths and for the deeper structure the knowledge must be obtained by geophysical methods. These methods are indirect and determine some of the physical properties from which identification of the materials and the depths at which they lie is possible though not always precise.

The generally accepted continental layering consists of the sedimentary rock strata of the surface which are variable in thickness from 0 to a maximum of about 15 km. overlying the granitic layer which extends to an approximate mean depth below sea level of 20 km. Below this layer there is the Intermediate Layer which, from the seismograph records obtained from near earthquakes, is known to exist at least in many parts of the continental crustal layers. It is identified by the velocity of compressional waves in it and there is good evidence that it is basaltic in nature. At a depth of between 30 and 50 km. there lies a discontinuity, again located by a study of earthquake waves, known as the Mohorovičić discontinuity. Below this there is a sudden increase in the velocity of compressional waves and from the measurement of physical properties in the laboratory and other considerations the most plausible interpretation is that the rocks lying below are peridotitic.

The Department of Geodesy and Geophysics of Cambridge University has undertaken measurements in the deep sea to find how the oceanic crustal structure differs from that under the continents. A certain amount of information is available from sources other than seismic refraction shooting but it is such that, while it gives a general indication, quantitative estimates of the thicknesses of the various layers have not been possible. Thus, the measurement of gravity at sea has shown that over the oceans the value of gravity is such as would be expected at sea level on the continents. If the oceans had been formed by the removal of the top 5 km. of the continental rocks and the resulting deep filled with water then, because of the relative densities of the rock and water, the value of gravity would be less at sea level than before the deep was formed. The amount of this difference would be the order of hundreds of milligals (1 mgal. $= 10^{-6}$ cm. sec.$^{-2}$) which is easily measurable, and, in fact, the mean difference is within a few milligals of zero. The deduction which can be made from this is that at some depth below the sea the mass deficit of the sea water is compensated for by the presence of denser rocks than would be found at a similar depth below the continents. This conclusion from the measurement of gravity at sea supports the principle of isostatic balance of large crustal features of the Earth's surface.

One of the more simple postulates for explaining the mass compensation for the sea water is to suppose that the lighter continental rocks are absent or thinned on the ocean floor. A petrographical study of the rocks from oceanic islands and from such features as the mid-Atlantic Ridge confirms this idea and further support for it is obtained from the measurement of the velocities of surface waves

[1] Paper read to Section A (Physics and Mathematics) at Belfast on September 9, 1952.

from distant earthquakes. These velocities are higher for paths lying over the ocean floor than they are for those over the continents and in general the higher the velocity of seismic waves the greater is the density of the rocks in which these waves travel.

These results give no precise indication of thicknesses or even of the types of rock forming the ocean floor, but they provide a basis to which must be added the results obtained from other sources such as seismic refraction shooting.

It has long been known that the surface layer of the deep sea bed is covered over most of its area with soft, recent oozes and clays of uncertain thickness. The origin of much of the material from which these sediments are made is organic, and consists of planktonic shells. These may be calcareous or siliceous and they are embedded in a matrix of clay which is usually of mixed origin, partly the finer clay particles derived from continental sources and partly the insoluble remains of organisms of which the main structure has been dissolved before reaching the sea bed.

There have been numerous deductive estimates of both the rate at which these sediments collect and thence of the mean total thickness which covers the rocks of the oceans. These estimates of thickness have been shown to be of the right order of magnitude but with the precise measurements which are possible by seismic refraction shooting they appear consistently to be too large.

There are numerous topographic features characteristic of the deep sea of which no mention has been made. There are sea mounts, coral atolls, the deep submarine trenches and canyons and the volcanic islands and these, while of great interest, cover but a small area of the oceans and are not part of the fundamental structural differences between the continents and oceans.

The Principles and Practical Details of Seismic Refraction Shooting at Sea

Seismic *refraction* shooting is one of the most powerful methods of prospecting available to geophysics in regions where the geological structure is completely unknown, for it not only provides the depths to interfaces in the Earth's crust but also the velocities of compressional waves in the various layers and thus an indication of their nature. With seismic *reflection* shooting, which in principle and in practice is easier, there are difficulties of interpretation except in areas where the general form of the structure is known. Reflection shooting simply calls for measurement of the time taken for sound from an explosion to be normally reflected from the various interfaces back to the surface and only allows the depth to be determined if the velocities with which compressional waves are propagated are known. On land, where it may be necessary to map the depth to a particular layer this method is powerful, for the velocities in the rocks forming the superposed strata may be known from borehole information or from known outcrops. In the deep sea, however, the knowledge is such that the identification of reflecting interfaces is impossible or, at best, uncertain. With the refraction shooting method an explosion is fired in the surface layer of the Earth and compressional waves spread out in all directions. By refraction some of the energy can be propagated along a lower layer in a direction parallel with the interface with a velocity characteristic of the material. This wave as it travels causes a disturbance in the upper layers which moves, in a direction parallel with the interface, with velocity representative of the lower layer. Thus, for an observer on the surface layer some distance from the explosion there will be a succession of phases moving with different velocities. The times at which these pass will not only be dependent upon the velocities but also upon the time taken for the passage of the waves from the surface to the deeper layer and back again. Hence by plotting the times of arrival of a particular phase against distance, a straight line is obtained ; the slope of this line is a measure of the velocity in the layer and the intercept on the time axis is dependent upon the time spent by the phase in travelling to, and returning from, that layer, and is therefore dependent upon the depth to the layer.

A disadvantage of this method is that no indication is obtained of the depths to layers in which the compressional wave velocity is less than the value in layers

lying above since, in such a layer, the incident waves will be refracted towards the normal to the surface and cannot therefore be propagated along the interface. Fortunately this disadvantage is not of major importance since it is rare to find a decreasing velocity with depth below the surface of the Earth.

This description of the method of refraction shooting assumes that the various layers are parallel and that any particular layer is homogeneous. This simplicity of structure is seldom found in the Earth's crust but nevertheless there are indications from the times of arrival which usually allow the structural interpretation. For example the dip of the layers can be determined by having a number of receivers at various distances from the explosion. If the beds are sloping then the times of arrival plotted against distance are such that the observations from a single shot on all receivers lie on a line of different slope from all shots on a single receiver. This difference in slope allows the measurement of the angle of dip.

Primarily, therefore, in this method of prospecting shots must be fired at varying distances from receivers of compressional waves. The most obvious way of achieving this requirement at sea is to fire the charge from one ship and to record the arrivals through the ground in another. The shot instant can be radio-transmitted from the shot firing ship and received and recorded in the receiving ship. The disadvantages of this method are twofold. Firstly there is the expense of running two ships and secondly only one result is obtained from every shot. It has however the advantage of simplicity. The Department of Geodesy and Geophysics at Cambridge has developed another system in which the receivers are attached to buoys, of which up to four are in use simultaneously at different ranges from the explosion. Each buoy contains an amplifier and radio-transmitter and has a separate receiver in the ship from which, for the shorter range work, the shots are fired. The difficulties of having aerials on the buoys which are longer than a few feet and more than 12 feet above sea level restrict the radio range to about 20 sea miles ; during the expedition of the summer of 1952 in the Eastern Atlantic in which the range was to be increased beyond this limit this restriction resulted in the use of two ships and the sono-radio buoys. The shot firing ship, *H.M.S. Scott* steamed away dropping one depth charge every eight miles, while the receiving ship, *R.R.S. Discovery II* remained in the centre of a line of some twenty miles in length along which the buoys were distributed. The instant of the explosion was transmitted by the main radio in *H.M.S. Scott* to the receiver in *R.R.S. Discovery II.*

For the receivers on land it is usual to place electromagnetic instruments which measure the ground velocity on or near the surface. At sea, these instruments are extremely difficult to place in position since the bottom of the sea, on which they must be laid, is often as much as 18,000 ft. below the ship. For this reason quartz crystal hydrophones, which measure the sound pressures in the sea caused by the ground movements, are suspended at about 100 ft. below the buoys. The charges likewise are fired near the sea surface at a depth not greater than 600 ft. This inability to place the charges and receiving instruments on the sea bed results in the introduction of an additional layer within the system of strata and restricts the amount of detailed information which could otherwise be obtained concerning the layer immediately below the sea.

The sono-radio buoy method of refraction shooting has the disadvantage in comparison with the two-ship method that it cannot be undertaken in bad weather. This is primarily due to the hydrophone disturbance produced by the drifting of the buoys through the water, but also because of the difficulties of launching and recovery of the buoys. When the hydrophone is connected with the ship the effect of drift can be eliminated by streaming out the cable during the interval for which the sounds are arriving ; this is clearly impracticable with the sono-radio buoys.

The Results from the Eastern Atlantic, 1952, and their Comparison with other Results

During the period of June to August 1952, the Department of Geodesy and Geophysics with the indispensable assistance of both the National Institute of Oceanography in allowing facilities aboard

R.R.S. Discovery II, and for a part of the expedition, of the Hydrographer of the Navy in providing *H.M.S. Scott* equipped with depth charges, carried out refraction shooting experiments at some eighteen different stations on the continental shelf and in the deep Atlantic in an area to the West of the English Channel. Of these stations, six were in the deep water of between 2,000 and 2,600 fathoms and four in the shallow water of less than 100 fathoms leading to the edge of the continental shelf. The remainder were in more landlocked areas of the English Channel and the Irish Sea.

The six deep stations showed a general simplicity of structure for the rocks below the sediments and confirmed the absence of the granitic layer. The Mohorovičić discontinuity appeared to lie, in the three stations at which its depth could be obtained, at between 9 and 12 km. below sea level. These figures must be compared with a depth of between 30 and 50 km. on the continents. The velocity 7·8–7·9 km./sec. below the discontinuity was consistently slightly less than the accepted value of 8·1 km./sec. for the same layer below the continents. A possible explanation is the tendency for the compressional wave velocity in rocks to increase with the stresses to which the rocks are subjected by their depth of burial.

Above the Mohorovičić discontinuity and below the sedimentary layer there appeared, from all the stations except the one at the foot of the continental slope, to be a layer with a velocity varying between 6·3 and 7·1 km./sec. This velocity range is excessive for the granitic layer of the continents and corresponds with that of the supposedly basaltic layer lying between the ultrabasic and granitic layers. At the single station at the foot of the continental slope the velocity was lower, 5·4 km./sec. but it is possible that the layering at this place is not so simple and that there is a higher velocity rock between this layer and the Mohorovičić discontinuity.

The thickness of the sediments was variable between 0 and 2·6 km. with an average of roughly 1 km. Samples obtained from the surface of this layer, lying immediately below the water, showed that at present and for the immediate geological past the sedimentation is largely of globigerina ooze with considerable quantities of clays which are of glacial origin. These glacial clays were deposited during the pleistocene glaciation and it is unlikely that they are of great thickness. For this reason the average thickness of 1 km. for the sedimentary layer is probably not appreciably greater than would be found in regions where the recent glacial deposits were absent, and is therefore probably typical of the Eastern Atlantic basin.

The variation in the thickness of the sediments and the topographic features of this basin show clearly that the conception of a smooth primaeval rock layer forming the crust of the deep ocean is incorrect. It appears to have been folded or faulted into structures which, while smaller in magnitude, are not unlike those which are found on the continents and this suggests that perhaps the great orogenies of the past have extended across the ocean basins.

This structural description of the Atlantic Ocean fits in well with the results obtained by refraction shooting from the other oceans of the world. This other information has been derived from three sources ; firstly there is the work of Prof. M. Ewing and his group working in the Atlantic ; secondly that of Dr. Raitt's group in the Pacific ; and thirdly the results obtained from the Atlantic, Pacific and Indian Oceans by Dr. T. F. Gaskell and Mr. J. C. Swallow during *H.M.S. Challenger's* world cruise of 1950–52.

Wherever in these expeditions the depth to the Mohorovičić discontinuity has been measured it lies at a depth below sea level not significantly different from about 10 km. and the main difference between the results appears to lie in the thickness of the sediment which in the Pacific is approximately half that which seems usual in the Atlantic. In both oceans, however, there are considerable variations in thickness and until more results are available it is difficult to be sure that the difference is general. The fact remains that the average thickness of the sediments throughout the oceans of the world is considerably less than the estimates of 3 km. which were deductively

derived. This does not necessarily imply that the oceans have existed for a shorter time than was supposed, but rather that estimates of the rate of sedimentation have for one or more of many possible reasons been incorrect for the geological past.

The differences in structure of the crustal layers of the oceans and continents gives strong support to the view that the oceans are permanent features of the Earth's crust. Whatever difficulties of identification may arise from knowing only one or two of the physical properties of the layers below the deep ocean sediments, there can be no escape from the important differences in thickness of these layers, and from the consequent difficulties which arise in postulating any mechanism which could remove some 15 km. of the Earth's crust from the oceans and place it at a higher level on the continents.

The general structural picture of the deep oceans derived from the refraction shooting experiments fits in with the result from the measurement of gravity ; thus by assuming the densities of the sedimentary, basaltic and ultrabasic layers to be such as would be expected from laboratory measurements on rocks of this type isostatic balance is achieved with the measured thicknesses.

There have, in the past, been suggestions that there are considerable structural differences between the Atlantic and Indian Oceans on the one hand, and the Pacific Ocean on the other. It was supposed that the former were intermediate in structure between the continents and the latter. The evidence from the seismic refraction shooting experiments does not support these views and apart from the possibility of there being a greater thickness of sediments in the Atlantic than in the Pacific the crustal structures appear to be the same.

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Much geophysical work remains to be undertaken in the oceans of the world in order to avoid the speculation which results from the comparatively small number of experiments which have been carried out to date. Nevertheless although a new picture of oceanic structure is being drawn from geophysical measurements there is little evidence from other sources which conflicts with it, and therefore no reason to suppose that further experiments will fundamentally change it.

The difficulties and expense of this oceanic research are such that progress will be slow, although, with the newly developed techniques and with the improvements which we can expect in the future, it will be sure.

THE BEHAVIOUR OF SOCIAL INSECTS

At the Association's Annual Meeting in Belfast, 1952, a part of Section D (Zoology) devoted Friday, September 5, to the subject of the behaviour of social insects. During the morning session, in a paper prepared by Professor A. D. Peacock, Dr. A. T. Baxter and himself, Dr. J. H. Sudd (University College, Dundee) discussed colony formation in Pharaoh's Ant; Dr. D. M. Vowles (University of Oxford) read a paper on individual behaviour patterns in ants; Mr. S. J. Holt (Nature Conservancy, Edinburgh) spoke on the foraging activity of the Wood Ant (*Formica rufa* L.); and Professor J. E. Webb (University College, Ibadan) read a paper on the swarming behaviour in termites—an adaptation to social life. During the afternoon session Mr. C. R. Ribbands (Rothamsted Experimental Station) gave his paper on new evidence concerning the 'language' of honeybees; Dr. C. G. Butler (Rothamsted Experimental Station) discussed the behaviour of worker honeybees at the hive entrance and showed a film by way of illustration; and Mr. G. D. Glynne Jones gave his paper on chemo-reception in the worker honeybee which was also illustrated with a film. Dr. C. G. Butler has edited the papers.

THE BEHAVIOUR OF ANTS

Colony Formation in Pharaoh's Ant (*Monomorium pharaonis* L.)

read by

Dr. J. H. Sudd

For about eight years now members of our department have been studying the little yellow house ant, *Monomorium pharaonis* L. In temperate lands this tropical animal has established itself in various artificial tropics—kitchens, bakeries and so on. It has not been found nesting out of doors except in the tropics. Wheeler thought that, in general, ants can found colonies in one of two ways. Usually a sexual couple, or a fertilised queen, leaves the parent colony and raises a brood which is the nucleus of a new colony. In others there is some kind of swarming in which a sexual couple and a number of workers found the daughter colony. Wheeler thought swarming to be uncommon in temperate species. In *Monomorium*, in laboratory cultures at least, no swarming strictly speaking occurs, although large and crowded cultures may become very restless and males may sometimes use their wings a little. Mating takes place in the nest. We have never been able to start a new colony with sexual forms alone; that is, with one or more fertilised queens, or with queens and males. This is not simply because queens must be fed by workers, as queens will feed themselves on food provided, and isolated queens will lay eggs. Workers do 'feed' queens, but this seems to be a 'ritualised' piece of behaviour. Queens often seem to damage or even eat eggs.

What is even more remarkable is that we have never succeeded in founding a colony with a population of one or more queens and a number of workers.

Our laboratory colonies are usually founded by workers and young stages with or without queens. In the case of queenless colonies the success of the colonies depends, of course, on the ability of the workers to raise one or more sexual couples. The presence of a queen, however, is by no means essential for the successful founding of a colony; in fact there is some evidence that while successful colonies may be founded by populations of workers with eggs, the same population with a queen usually fails. It seems possible that established colonies have a habit of wandering as a whole, or of dividing and then rejoining. It may be, then, that it is not legitimate to think of the population of an infested building as consisting of several discrete and static colonies.

We had supposed that the success or failure of a colony founded by workers with preadult stages might be influenced by the number of workers, and by the proportion of workers to preadults. It has been the experience of most workers in this department that it is difficult to found a colony with fewer than 50 workers, using our usual methods. It might be that there is also a certain value of the ratio of workers to preadults below which a successful colony cannot be formed. This, however, is a matter which might regulate itself; if there are more larvae than the workers can feed, some larvae will die until a viable ratio is obtained. The lowest ratio with which we have been successful was 40 workers to 53 preadults, 21 of which were prepupae.

The upper limit of this ratio is possibly of more importance than the lower limit. When there are many more workers than are necessary for the tending of the young stages (and the various other duties) it is probable that overhandling of eggs occurs, causing a high mortality. This in fact might be the cause of the failure of colonies founded by queens and workers alone. Although a number of eggs are laid over some days, they appear a few at a time and may be very quickly destroyed. We know that eggs are crushed by the clumsiness of workers.

The situation is, then, that colonies can be founded by populations of over a minimum of 50 workers along with about an equivalent number of preadult stages, and with or without queens. Queens alone or workers with or without queens cannot found a colony unless they are supplied with preadults. Unfortunately we have insufficient knowledge of the behaviour of the workers to understand the significance of these findings, but we have begun to study worker behaviour from this point of view. They can perhaps be explained in terms of a competition for the services of the workers. Some preliminary experiments with small numbers of workers seem to show that queens compete with larvae for the attention of the workers. When a queen is added to a small population of workers and larvae the queen appears to win this competition, so that the queen is ' ritually fed ' by workers almost continuously. This is reflected by a fall in the number of workers tending larvae. After two or three hours, however, one finds the queen deserted and more larvae being fed. The feeding of queens by workers appears to be a truly instinctive act, with a releasing mechanism, and from what has been said already it appears to have a variable threshold.

In a system of this kind an unbalance of the population can evidently lead to a breakdown of the system. It seems possible that colonies with too few young stages do not provide sufficient employment for the workers and a sort of inflationary situation of too many workers chasing too few eggs results, in which eggs may be destroyed by overhandling.

Our records seem to show that the spread of infestations of *Monomorium* is not as simple a matter as might be thought. It is no doubt possible for *Monomorium* to be spread from, for example, bakery to kitchen, by the inclusion of ants in a cake. However, if our laboratory results are valid in the field there would have to be quite a fair number of ants in the cake for a new and successful infestation to be set up; one queen would not be sufficient, nor would any number of workers with a queen. The cake would, in effect, require to have been already colonised by ants, otherwise it would contain no young stages. If the cake only contained a few workers surprised while feeding or collecting food, although ants might appear in the kitchen they could not establish a colony. Even if these ants had some young stages with them, unless there were about fifty adults their chance of founding a successful colony is very slight.

Individual Behaviour Patterns in Ants

by

Dr. D. M. Vowles

It is probable that the social Hymenoptera evolved from solitary, carnivorous, wasplike insects. The evolutionary process, first deduced by Wheeler, involved a series of stages whereby the mother came to remain with her brood, feeding and tending them throughout their development, rather than leaving bulk provisions with a deserted egg, as her ancestor had done. At a later stage the mature forms,

reared by the mother, remained with her and assisted her in maintenance of the nest, care of further brood, and in foraging. Eventually the full caste system arose, in which the colony's queen, and the males, are maintained solely for reproductive purposes, while the workers take on all the other duties of the colony.

The genetic constitution of the queen and the worker is the same. The queen and the worker must therefore possess in common the nervous mechanisms responsible for their instinctive behaviour. Queens of many primitive species of ant forage and build nests in the initial stages of colony foundation. It is known also that workers can mate and lay fertile eggs ; this strongly supports the hypothesis that workers contain all the neural mechanisms for reproductive behaviour, and the queen all the mechanism under-lying the workers' type of maternal behaviour. If this is so, then the normal disuse of these mechanisms remains to be explained.

The efficient running of a colony would be disrupted if workers did behave in a feminine fashion, ceasing their normal duties in order to court, mate or lay eggs. Specialisation of function within a society undoubtedly leads to more efficient organisation. One can understand, therefore, why evolution has acted to suppress reproductive behaviour in workers. There remains the problem of the method by which this was achieved.

If the concept of drive is accepted the distinction between the queen and the worker may be explained on this basis. What the workers lack is not the nervous connections for sexual behaviour, but the drive which would motivate it. If this is so then one must distinguish between the various subdrives of the reproductive instinct ; such drives corresponding to courtship, mating, egg-laying, nest-building, care of young, care of nest, and foraging. In an established colony of a species such as *Myrmica ruginodis* Nyl., the first three are present in the queen, the last four in the worker.

To suppress behaviour by suppressing the drive rather than the nervous executive mechanisms has the advantage that any mortality to the queen may not prove fatal to the colony, for workers can take over her functions.

Some of my own preliminary experiments with workers of the American Carpenter Ant, *Camponotus pennsylvanicus* suggest that a physiological differentiation may accompany the morphological differences in different castes. The workers of this species have three castes—majors, intermediates and minors. All three castes can and do perform all duties of the colony. But normally the proportions of each caste engaged in different activities differ. All three castes will show attack behaviour after presentation of a noxious stimulus, such as a piece of filter paper soaked in formic acid. However the threshold for attack is different in the different castes. A clean fragment of filter paper introduced into the nest is ignored by the majors, attacked by intermediates and avoided by minors. If the paper is soaked in formic acid it is attacked by majors and intermediates and fled from by the minors. If a minor is ' worried ' with the acid paper it will attack. A possible interpretation of these results is that the threshold of the attack activity is lowest in the intermediates, highest in the minors and between the two in the majors. This implies that under natural conditions slight threats to a colony are dealt with by the intermediates, violent threats involve the majors, while in extreme cases all three castes will resist aggression.

It is well known to many ant-keepers that the greater the number of young the greater the foraging activity of a colony. Dr. T. C. Schneirla has worked this out in detail for Army Ants of the genus *Eciton*. A similar phenomenon was shown by Haskins and Haskins in *Myrmecia* which also have carnivorous larvae. When only eggs are present the workers forage sporadically and individually, collecting nectar. There is no subsequent regurgitation in the nest. When the larvae are present, however, the foraging becomes marked and continuous, and the workers bring back insect booty, which they deposit among the larvae. When pupation occurs the workers' foraging again becomes sporadic and individual.

I was able to confirm these types of relationship in *M. ruginodis*. It was found that increasing the number of larvae increased the foraging activity both in terms of numbers of foragers and the

activity of individuals. Pupae and eggs did not cause this increase. Old larvae caused more activity than younger. Royal larvae caused greater activity than worker larvae. The presence of larvae caused a greater proportion of chopped cockroach than sugar water to be taken than under other conditions.

There seems little doubt that the larvae provide a stimulus for foraging by the workers. The observations on *Myrmecia* and *Myrmica* make it clear that in these genera the foraging activity that is stimulated is for proteinaceous food, rather than for sugar. One must distinguish between the workers' selfish foraging, and their maternal activity. Schneirla and Haskins both agree that it is the violent jerking movements of the larvae which is the specific excitatory stimulus. It is not yet clear how specific is the ' excitement ' aroused by such stimuli. More work is needed on this subject, as the concept of a general nervous excitation, at least in Arthropods, is becoming increasingly more acceptable than specific reaction energy.

If a worker encounters one of its colony's brood out of the light it usually seizes the young form and carries it back into the darkness of its nest. If a pile of larvae is so discovered the worker carries them back one by one. This brood retrieving response was investigated in *M. ruginodis*. A worker will retrieve in this way eggs, larvae and pupae. Immobilisation of these by anaesthesia with carbon dioxide did not affect the worker's behaviour. Movements by the brood are therefore not important in this activity. An empty skin of a larva or pupa is not usually retrieved, but such a skin filled with particles of mud is sometimes retrieved. Mud models, even with the colony odour, are never retrieved. This suggests that three of the stimuli involved are solidity, suface texture and lighted environment. Other stimuli are most certainly involved. Odour is undoubtedly important, but the correct colony odour is a prerequisite for all social activities, and may act by inhibiting attack or flight rather than by exciting behaviour. The hunched shape of the larvae and pupae may also be important.

While the releasing stimuli have not been fully isolated in this analysis they have at least been shown to differ in the two types of behaviour—foraging and brood retrieving. The results of other experiments indicate at the least, that the brood retrieving and foraging behaviour differ in factors other than the stimulus situations alone.

The two behaviour patterns so far discussed both involve brood-worker relationships. As a contrast to this an analysis of a worker-worker activity was started, the activity being mutual feeding by regurgitation. The observations and experiments were carried out on the Carpenter Ant.

In mutual feeding one must distinguish between the behaviour of the donor and the acceptor. The dominant factor in this activity seems to be the donor's ' desire ' to feed other ants. A replete forager, full of sugar water, returns to the nest and thrusts its face into the face of another worker, opening its mandibles, protruding its labium and sometimes palpating the potential acceptor with its antennae. Often the donor has to go from ant to ant before finding a willing acceptor.

Acceptance can be elicited by a model and the impression is very strong that the acceptor's antennae are used for orientation and not for stimulation. The structure of the head is apparently of little importance to the acceptor. It seems that a potential acceptor will take food from any source which it discovers. One often sees an ant leaving the nest, molesting other ants as if soliciting food and, when unsuccessful, feeding from a pool of sugar water. There are no grounds therefore to separate the acceptor's behaviour from normal foraging activity. When a forager becomes a donor, however, its behaviour is changed. This change is presumably due to the presence of food in the gut, and has two facets. Firstly the donor starts actively to search for an acceptor, and secondly it is prepared to regurgitate. The actual stimulus for regurgitation is not yet known, but it seems that a touch on the labium may be the most important part of it.

It has been impossible, in so short a time, to describe at all adequately the behaviour of ants. Implicit in the discussion has been the theme that all the complex behaviour of a colony is due to the behaviour of individuals. A preliminary attempt has been made to study

the behaviour patterns of an individual, to isolate specific responses and the specific stimuli responsible for those responses. This analysis is only just beginning but the results show how promising such a method of attack can be.

On the Foraging Activity of the Wood Ant (*Formica rufa* L.)

by

Mr. S. J. Holt

Ants' nests may remain in one place for many years, each colony developing a stable foraging system, from the area covered by which individuals from other colonies are said to be excluded. The Wood Ant behaves in this way, and provides an excellent subject for study since it usually forms clearly defined narrow tracks. Thus in the passage of workers to and from the nest they are at certain points concentrated and can easily be counted.

The main site surveyed was at Glen Coninish, in Perthshire, a small relic of Caledonian forest with at least 60 hills of *F. rufa*. A large isolated nest was chosen, having five branched tracks radiating from it, on each of which suitable census points could be set up. Attention was first concentrated on one of these which led to a pine tree about 70 feet away from the nest. It was found that the number of workers passing a census point in either direction per minute decreased as its distance from the nest increased, showing that outgoing ants were 'leaking' from the track at the rate of about 0·5 per cent. per foot, and that returning ones were infiltrating at the same rate. In fact only about 50 per cent. of those leaving the nest by this track reached the base of the pine tree.

The subsequent dispersal of the wanderers was measured at various distances from the track. The density of foragers decreased with increasing distance from the trail, the logarithm of the density being, apparently, a linear function of the distance.

A simple mathematical model gives this density distribution. If ants, when they leave the path, travel more or less at right angles to it—direct observation suggests that this can reasonably be assumed—and the food particles are distributed randomly over the searched area, then the probability that food will not have been secured after a perpendicular distance x has been traversed is given by $P = e^{-x/p}$ where p is the 'mean free path.' Now this latter is inversely proportional to the number density, D, of the food units, and also approximately to the effective *diameter* ($= 2r$) of those units, this being determined by the average distance to which an ant has to approach before sensory contact and recognition of the prey are effected. So that $p = \frac{1}{2rDs}$ where s is the proportion of successful contacts. A steady state is established where the leakage per foot (I) is equalled by the infiltration rate, and the density of foragers at a point at distance x from the path will be $\frac{2I}{v.e^{-2rDsx}}$ where v is the average speed over the whole journey to and from the track, including any stationary period whilst the prey is being secured. That the latter is small compared with the time spent searching is shown by the fact that only very occasionally was the act of securing prey observed whilst sampling was in progress.

This equation can be expected to apply to the distribution normal to a straight trail even if workers wander away from that direction, but needs to be modified to $\frac{2I}{v(R+x)e^{-2rDsx}}$ where they are leaving the nest directly and not using established paths, as is occasionally the case. This has been confirmed at another site where a smaller colony has a single short track leading to a pine tree on its north side, but the majority of foragers leave the nest on the south and disperse over a wide flat area.

Returning to the observations made at the first site, the following results were obtained on two separate days :—

	(*a*) *Late August*	(*b*) *Mid-June*
Average shade temperature . .	18° C.	9° C.
I per foot per minute	0·54	0·12
$2I/v$	5·025	2·243
Giving — v (ft./min.)	0·22	0·12
$2rDs$	0·083	0·024

The difference between the two values of v can probably be accounted for entirely by the temperature difference. Direct evidence of this temperature effect has been obtained by measuring track running speeds in various ways. Over the range 9–21° C. the data were adequately graduated by a logarithmic curve, with $Q10 = 2{\cdot}7$.

If r and s were the same in each experiment we can infer that the density of available food organisms during the August experiment was 3–4 times that in June, and this is in keeping with subjective assessments of relative abundance of insects. The absolute prey densities can be obtained if r and s can be estimated. Observation of ants catching midges settled on the leaves of a rowan tree in the area and also of their reaction to piles of food placed in their path suggest that r is about 0·1 feet, not more, and that s for midges is a little less than one-half. We shall probably not be far wrong if we take $2rs$ to be a little less than 0·1, thus giving prey densities of about 1 per sq. ft. and 1 per 4 sq. ft. respectively.

In the foregoing calculations it has been assumed that the prey density was uniform over the foraging area, but if the ants were causing any considerable mortality by their predation, the density of prey would be higher away from the track than close to it, since there is no reason to expect the replenishment rate to be a function of distance from the ant trail. There is, however, a continual flux in the prey population, tending to nullify any effect of this kind. Furthermore the effect of any relative depletion near the trail would be that more ants would pass through that zone and feed at a greater distance away.

It is clear that the main effect of a change in prey density in such a system is on the average distance travelled by the predator in its search for food and hence on the time taken for a round trip and the number of trips which can be made per day. This, together with the effect on trip time of the temperature variation, is probably sufficient to account for the difference in rates of flow past the census point (191 and 52 per minute) found in these two experiments.

If N individuals are foraging and they are distributed more or less evenly round the circuit, the rate of flow through a bottleneck (i.e. the track near the nest) is $F = \frac{N}{\dot{\tau}}$ where $\dot{\tau}$ is the harmonic mean of the individual trip times. This may be estimated by marking a number of individuals as they pass a census point near the nest on the outward journey and timing their return. The arithmetic mean of these absence times, $\bar{t}$, plus the time spent in the nest unloading and preparing for the next trip is estimate of $\dot{\tau}$.

Fifty outgoing ants on one track were marked with green paint. In four hours 42 of these were seen and $\bar{t}$ was 120 minutes. The total rate of flow along all five tracks was estimated at the same time as 370 per minute giving a value $N = 370 \times 129 \simeq 48{,}000$ if it is assumed that the trip time on the other tracks was about the same as on the one tested. This figure is a minimum since the time spent in the nest and also any ants going straight out from the nest and thus missing the census have been ignored—the latter in this case being certainly not more than 5 per cent. of the total, though their trip time might be expected to be rather less than the average. It has not been possible to estimate the time spent in this nest per trip, but this factor was measured, again by marking at a site more suitable for the purpose. The results showed that particular individuals do not always use the same track but nevertheless tend to emerge more often on the one that they enter by than on the other. The average time spent in the nest was half an hour, and if this value is applied to the Tyndrum data we get a revised value for N of 60,000–70,000 which is consistent with the estimates of the total worker population of hills of this species made by investigators who have made direct counts by digging up nests. For some purposes indeed it is of more value to know the foraging power of a colony than the total numbers, determining as it must the rate of reproduction and growth of the population.

The number of trips completed per minute on one track followed rather closely the curve of temperature throughout the day, and in 14 hours from 6.30 A.M. to 8.30 P.M. it has been estimated that 60,000 complete trips were made on this track, making about 300,000 for the whole colony. The mean weight of workers on

the outward journey was found to be 0·0098 gm., differing significantly from the weight of 0·0117 gm. of arrivals bearing honeydew (81 per cent. of total). A load of honeydew therefore weighs 0·0019 gm. and it was found that the remaining 19 per cent. each carried about 0·008 gm. of solid food. The total intake of food is therefore at least 800–900 gms. per day of which 44 per cent. is honeydew. The biomass of foragers is about 700 gms.

These results suggest that it might be possible to carry out a detailed survey of the ant population of a small wood and obtain a measure of its changes and its effect on the insect populations which constitute the bulk of its food. To do this, however, one would have to have some idea of the exchange rate of prey between the trophoporic fields of the ant colonies and the surrounding area and this would be difficult to obtain.

THE BEHAVIOUR OF TERMITES

The Swarming Behaviour in Termites —An Adaptation to Social Life

by

Prof. J. E. Webb

As Grasse has pointed out, swarming in termites refers to a period in the life history of the insect in which the social attraction which normally exists between all castes in the colony breaks down, or is effaced, so that the behaviour of the winged forms is equivalent to that of a non-social species. He holds that, in this respect, the swarming of termites differs profoundly from that of the bees which separate into two colonies, one colony remaining in the hive and adopting a new queen, while the second colony emigrates with the old queen, so that at no time is the sexual form separated from the attendant castes.

A second fundamental difference between the termites and bees lies in the fact that in termites there is both a king and a queen in addition to soldier and worker castes. In the bee there is no permanent king. Before a new termite colony can be founded both individuals of the royal pair must be present and contact between them is first achieved during the process of swarming of winged males and females. In swarming not only does the male have to find the female but also to remain in association with her throughout the hazardous period before the first chamber of the new nest is formed. The fact that they do survive to the extent that termites are often the commonest insects in the regions where they occur can be attributed largely to the complex pattern of behaviour that winged termites show during the process of swarming.

The species in which the behaviour of the winged forms during swarming has been studied by Mr. J. H. Elgood and myself is *Macrotermes nigeriensis*.

Swarming in *M. nigeriensis* usually occurs once or twice annually during the rainy season. The first major rains of the year following the dry season usually herald the swarming of the termites which, in *Macrotermes nigeriensis*, takes place at dusk or immediately after night-fall on the following day. Male and female alates emerge from the nest in large but approximately equal numbers. At this time they are positively phototactic and, flying strongly, are attracted by any source of light such as the lighter western sky, the moon, or the artificial lights of man.

On reaching the ground the female usually sheds her wings within a few minutes with a jerking movement of the body. The males fly in search of the females, making short flights interspersed with periods of searching on the ground when they run rapidly in all directions. They do not as a rule shed their wings until a female is located when they drop them in a matter of seconds. When the male has found a female he caresses the hind end of her abdomen with his mouthparts and antennae and this action stimulates the female to run forward with the male pursuing her in ' tandem.' As soon as contact is established the female, at least, becomes negatively phototactic, running away from light in search of a suitable site for nest building. When the site has been selected by the female, the tandem is broken and both she and her mate begin to excavate the first chamber of the new nest. If, before selecting the site, the pair become separated, then the female stops and remains stationary with her abdomen raised and flattened while the male resumes his caresses and the

female once more runs forward taking the lead. The pair then commence to burrow in the soft earth hollowing out a small chamber which they enter and then seal completely from the inside. In this chamber mating takes place and eggs are laid about six weeks later. The small colony lives on the body reserves of the male and female until workers are sufficiently developed to extend the colony and seek food from outside sources.

The purpose of this paper is not to analyse the details of the behaviour pattern but to point out some of the ways in which it seems that the swarming behaviour of *M. nigeriensis* in particular and termites in general is adapted to combat the difficulties with which the insect is faced at that time.

In most social insects the life of the male is transitory and ends after fertilisation of the female, the female then proceeding alone to found the new colony. In termites, however, the male, once having made contact with the female during swarming, continues to be associated with her throughout her life, the royal pair occupying a special chamber in the termitarium. The first problem to be solved in the termites, therefore, that of achieving contact and then maintaining the male and female in association from the time that contact is made until a subterranean chamber has been excavated, is one which does not arise in other social insects. This difficulty is overcome by the behaviour of the alates themselves.

The second difficulty arises from the fact that winged termites with their bodies packed with food reserves, chiefly fat, are much sought after by a variety of insect-eating animals. Emergence from the nest at night-fall reduces the chance of capture and gives all the hours of darkness in which a pair can select a suitable site and enclose themselves in the safety of the nuptial chamber.

Termites normally live within a comparatively narrow range of temperature and humidity requirements. In the established nest there is considerable control over environmental conditions so that during the dry season termites are able to tap water sources well below ground level. To do this, however, a large colony with extensive underground galleries is necessary. These are conditions which are not present in the newly formed colony. It is, therefore, important that swarming takes place at the onset of the rains for this means that not only will the soil be moist and soft, permitting easy excavation, but also that it is likely to remain so throughout the rainy season for a period long enough to enable the new colony to become well established, when it will be able to regulate its own humidity conditions.

A less urgent problem, though one of great evolutionary importance, is the provision of an adequate chance for mating between different colonies. Where the number of alates from each nest is so large and the period they spend above ground so limited, the chances of mating between individuals from different nests or different genetical lines will clearly be negligible unless swarming occurs from more than one nest at the same time. It is here that the simultaneous emergence of alates from a number of nests following the first rains is of importance in securing variations which would otherwise be absent from pure bred lines.

In conclusion it can be argued that the entire pattern of behaviour of the swarming alates is adapted to ensure a measure of survival under the difficult conditions which obtain when they leave the protection of the parent nest, seek a mate and found a new colony. Perhaps the most important feature in the sequence of events in swarming lies in its precise timing, for on this depends not only the survival of a proportion of the alates and the young colonies they form, but also the mating in at least some cases between alates from different parent stocks. The intricate behaviour of the alates themselves during swarming is a subsidiary mechanism to increase the chance that a male will locate a female and remain with her to start the new colony.

THE BEHAVIOUR OF *APIS MELLIFERA*

New Evidence Concerning the 'Language' of Honeybees

by

Mr. C. R. Ribbands

The method of organisation of the community life of the social insects presents

the biologist with a fundamental problem. As the colony has evolved in size and complexity the need for methods of communication between the members of the colony has increased. Part of the so-called 'language' of honeybees has been described in the well-known researches of von Frisch but his investigations were only concerned with recruitment to crops by successful foragers. There must also be other types of communication, concerned with co-ordinating the various activities within the colony; these are the subject of this talk.

Each colony is one family, produced by one single fertile female, the queen, which lays the eggs from which the other bees develop. The colony contains 10,000–80,000 worker bees, which carry out the varied tasks required for its maintenance. Each worker is capable of carrying out all the tasks, at different times.

It has been known that young workers undertake brood-rearing, older ones carry out other duties inside the hive, and the oldest ones go foraging, so it has been supposed that the duties were allocated among the workers on an age basis. However, I took a group of workers, all born on the same day and living in the same colony, and marked them with coloured paints so that they were recognisable as individuals. Study then proved that there was a wide range in the age at which they commenced their last task, foraging. This result showed that age was not the most important factor in determining the allocation of duties.

The various duties are all concerned with the handling of food. Moreover, the proportion of workers required for each task depends upon the supply of food available. Therefore I guessed that there might be a mechanism by which the distribution of food in the colony would create the need for re-allocation of duties and at the same time satisfy that need. This could not easily happen unless changes in food supply were quickly appreciated by all the bees of the colony, so I approached my Rothamsted colleague, H. L. Nixon, and together we designed an experiment to examine this possibility.

Six workers from a colony of 24,500 honeybees were trained to forage from a small dish containing sugar syrup, and given individual paint marks. A minute quantity of radioactive phosphorus was then stirred into one tablespoonful of sugar syrup, and the solution was put in a dish on the site at which the six marked bees were foraging. These bees took 3¼ hours to carry this radioactive syrup to their colony. Two hours afterwards large samples of bees were collected from the colony, and examined individually for radioactivity. About one-fifth of them were radioactive, and must have obtained a sample of the syrup. A day later at least one-half of the adult bees in the colony had obtained a share of this tablespoonful, and two days later all the older larvae had received some. Thus this tracer technique demonstrated that there was a widespread food transmission throughout the colony.

This food transmission provides sufficient basis for the allocation of duties among the workers. One may suppose that each of the tasks is being performed by a group of workers of various ages and more or less suited to their task. All the workers of each group share a common and much-transmitted food supply, and in consequence any surplus or deficiency in that supply can be evenly appreciated throughout the group. Any surplus would cause the oldest bees, least fitted for that task, to leave that group and to join whichever senior group is then in need of recruits. In this way food transmission is the foundation upon which the colony is organised.

Experiments which I carried out in collaboration with Dr. Hans Kalmus have demonstrated another important role of this food sharing. It enables honeybees to emit odours which their companions can recognise and can distinguish from the odours emitted by the honeybees of other colonies.

A simple experiment, often repeated, has demonstrated the ability of honeybees to recognise their companions. Two small glass dishes were placed on the ground about one yard apart and about 100 yards away from two colonies of honeybees. Dish *a* having been filled with sugar syrup, a group of honeybees from colony *A* were trained to forage from this dish and their thoraces were marked with white

paint. During the following night the entrance of colony *A* was closed, so that its bees were unable to fly. Next day dish *a* was left empty while dish *b* was filled with sugar syrup and a group of bees from colony *B* were trained to collect this syrup and had their thoraces marked with blue paint. The entrance to colony *A* was then opened, and syrup was supplied at both dishes. The marked bees from both colonies then visited the dishes to which they had been trained, and unmarked recruits soon came to join them. These recruits were marked, on their abdomens, with paint of the same colour as that on the thoraces of the trained bees visiting the same dish. That evening colonies *A* and *B* were searched and all marked bees were killed and recorded. It was found that most of the recruits to dish *a*, to which marked bees from colony *A* were trained, had also come from colony *A*, while most of the recruits to dish *b* had come from colony *B*. Thus the marked bees at both dishes had attracted their comrades, which must have recognised them.

A modification of the experiment showed that the recruits were attracted by the smell of their companions presumably emitted from the scent gland on the abdomens of the bees.

The distinctive odour is not distinctive for each individual, but for all the foragers of any one colony. Only one hypothesis can provide a likely explanation of the facts of mutual recognition. We suppose that the extensive food sharing ensures that all the foragers of a colony share an identical diet, from which they produce identical waste products. Some of these waste products are modified forms of the scents of flowers from which the food was gathered, and these scented wastes are emitted from the scent glands and used as a means of mutual recognition.

The existence of the distinctive odours having been established, it must be obvious that they have important uses quite outside the context in which they were demonstrated. In particular, they must be of value in the defence of the community against robber bees from other colonies. This usage has remained obscure because robber bees develop a nervous type of behaviour which is quite distinctive, and it has hitherto been supposed that this behaviour would alone suffice for their recognition.

The following experiment, carried out last October, demonstrates the use of distinctive odour in defence. The entrances of two colonies, one of black bees and the other of yellowish ones, were reduced to very small openings, one on the left and one on the right side. The two colonies were then moved together so that their entrances were only 2 inches apart. Many bees then tried to return to the wrong colony, but their behaviour was exactly as it would have been if they had alighted at their own entrance. Nevertheless they were seized, mauled and repelled. A proportion of the intruders were killed, and soon there was a large pile of corpses below the two entrances ; in two days less than a dozen bees succeeded in entering and staying in the wrong colony. The need for defence of the colony varies with the season. In a good summer honeyflow honeybees everywhere are busy on crops, and there is no robbing. When the experiment was repeated in such conditions no fighting occurred, and the foragers of either colony returned to the two entrances indiscriminately. Intermediate results occurred in intermediate conditions. In robbing conditions whether strangers succeed or fail in entry seems largely a matter of luck. A small number of strangers trying to enter may nearly all be repelled, but a larger number may be more than the guards can cope with and a proportion will then get through and will eventually become accepted in the other colony.

In conclusion, these results together demonstrate that food sharing is not only the basis for the allocation of duties among the workers in the manner most suited to the needs of the colony, but it is also the foundation of the distinctive colony odours which enable the members of a colony to distinguish their comrades, both in the field and when defending the colony. Moreover, food sharing enables successful foragers to tell their comrades about the quality and scent of their booty, as von Frisch demonstrated. For these three reasons food forms most of the vocabulary in the ' language ' of honeybees, and the transmission of food from bee to bee provides the most important method of

communication in the honeybee colony, as well as the most primitive one.

Thus the complicated community life of the honeybee is founded upon this very simple process.

The Behaviour of Worker Honeybees (*A. mellifera*) at the Hive Entrance

by

Dr. C. G. Butler

I WANT to outline the results of some observations at hive entrances which Mr. J. B. Free and I have made in order to ascertain the relative importance of scent and behaviour in enabling a bee to recognise members of her own colony and to distinguish them from intruders from other colonies.

In experiments, when all colonies appeared to be quiet, the hives of colonies were interchanged as quietly as possible thus causing returning foragers to drift to hives other than their own, and the reactions of the bees towards the intruders were noted. Each hive was then thumped vigorously to disturb the inmates—further observations were then made. It was found that out of a total of 113 returning foragers seem to enter the hives of other colonies before these colonies had been disturbed, only 4 (3·5 per cent.) were intercepted by bees and examined, whereas of 102 foragers seen to enter the same hive after their inmates had been thoroughly disturbed 65 (63·7 per cent.) were intercepted and examined. None of the intercepted bees were, however, actually stopped by the guards, nor did they hesitate to run quickly into the hives.

In addition after the colonies had been disturbed, a few bees which were not carrying pollen were intercepted by guards, stopped and submitted to detailed examination, and in some cases were 'mauled'—i.e., had their legs and wings pulled about.

Thus there seems to be a great difference in the behaviour of the bees of alerted and unalerted colonies towards intruders from other colonies. It was therefore decided to attempt to find out what stimuli cause the bees of a colony to become alerted other than the somewhat abnormal stimulus of violent vibration of their hive.

In 1951 Lecomté described experiments in which bees kept in small cages were induced to attack dead bees and various artificial bee-like models when they were rapidly bobbed up and down on the ends of cotton threads. His description of the way in which the bees in the cages attacked these lures is very reminiscent of the behaviour of guard bees attacking a robber bee. We therefore carried out experiments in which dead bee lures were bobbed in front of the hives of unalerted colonies for periods of 5 to 10 minutes. It was found that the bees attacked the lures, guard bees appeared at the hive entrances, and the colonies remained alerted for some time. It was found that lures consisting of freshly killed members of the experimental colony were just as effective in alerting this colony as were lures made of bees from other colonies. This suggests that it was the bobbing movement of the lures, which is similar to the flight of a robber bee when she approaches the entrance of a hive which she is about to plunder, which was the principal factor in provoking an attack—and not the scent of the lure itself.

It was concluded that the presence of robber bees, with their characteristic flight, around the entrance of a hive is sufficient to alert the inmates of this hive.

We have also been able to show that the presence of a number of bees that have been caused to drift inadvertently to the hive of another colony is sufficient, sooner or later, to arouse the suspicions of some of the members of the recipient colony and cause them to examine and recognise them as strangers by their body odours. This leads to mauling of the strangers and to the general alerting of the bees of the colony. Thus we can conclude that under natural conditions the bees of a colony can be alerted in at least two ways :—

(1) By the presence of robber bees—to which they react quickly.

(2) By the presence of numbers of bees that have drifted from another colony.

Once a colony has become alert guard bees can be seen near the hive entrance. These guards assume a very typical attitude and watch the movements of bees flying overhead and approaching the hive

and attempt to intercept any bee which they see alight near them.

It seems improbable that colony odour plays an important part in enabling a bee to distinguish between her own hive and that of another colony, as a bee that has strayed to a strange hive will enter it even though members of the colony occupying the hive are exposing their scent glands at the entrance.

The type of behaviour a colony of bees exhibits towards intruders depends on whether or not the colony is in an alerted state. The recognition, by the guard bees of alerted colonies, of bees of their own colony would appear to depend exclusively on smell. Inspection of such bees lasts for 1–3 seconds and is made with the antennae only. Examination by guards of definite intruders is also made with the antennae and may also last for a few seconds only and be followed immediately by mauling.

After recognition of an intruder by her body odour the resultant action taken by a guard towards her appears to depend upon the behaviour of the intruder. Should the intruder be a returning nectar- or pollen-gatherer that has made a successful expedition she adopts what must be regarded as a dominant attitude in respect to the guard bees. She takes little or no notice of them and continues to run into the hive often with a guard closely pursuing her and examining her abdomen. Only very occasionally do such laden foragers submit to examination or mauling by the guards. The increased length of time spent by the guards in examining these ' foreign ' foragers in contrast to the rapid inspection of their own foragers indicates that they are recognised as intruders, presumably by their body odours.

A second category of intruders generally takes up a submissive attitude when intercepted by examining guard bees. These bees readily submit to examination and mauling. When the examining bee approaches the head of a submissive intruder the latter turns towards her and offers her food between her open mandibles. This offer of food is seldom accepted and after it has been refused, usually several times in succession, the suspect commences to ' strop ' her tongue. This behaviour pattern differs from normal tongue-cleaning in several important respects—for instance :—(*a*) the rate of stropping is higher than that of a bee that is cleaning her tongue in the normal way, (*b*) the number of consecutive strokes is greater—nor does such tongue-stropping appear to be related to the circumstances in which tongue-cleaning normally takes place. For this reason it is thought to be a displacement activity and may arise through the thwarting of the drive to give food or to enter the hive, or both.

In very few cases have intruders, which have adopted either the submissive or dominant attitudes to guard bees, been seen to be stung. The submissive bees are, however, very frequently mauled by the guards.

The examinees offer little or no resistance to mauling and have been seen on rare occasions to become entirely passive, passing into a condition of thanatosis. Some of the foreign bees which manage to enter the hive are ejected by members of the colony but a few may succeed in remaining and are later treated as members of their adopted colony. In such cases it seems reasonable to suppose that they have acquired the same odour as the bees of their new colony. This distinct colony odour appears to be acquired either by direct contact with other members of the colony, or perhaps, as suggested by Kalmus and Ribbands, through slight differences in the quality of the food being used in different colonies.

The attacking of robber bees by guards appears to be released by the characteristic horizontal darting of the robber bee. The robber is pounced upon without any prior antennal examination and consequently scent is thought to play little or no part in the recognition of the robber by the guard bee.

When a robber is seized by a guard bee she tries to break away. This behaviour releases in the guard the instinct to sting. The robber bee often responds by trying to sting the guard, in which case fighting usually continues until the death of one of them occurs.

It is concluded that although scent plays a part in the recognition of all intruders, except perhaps robbers, it is the subsequent behaviour of the suspect which determines the resultant actions taken by the guard bees towards them.

Chemo-reception in the Worker Honeybee

by

Mr. G. D. Glynne Jones

I should like to describe some experiments which I have carried out as I believe that, although they were not undertaken to study the behaviour of bees, *per se*, the technique used and the results obtained may serve to stimulate fresh thought.

Laboratory experiments with honeybees are often rendered valueless because the environment rarely permits of normal behaviour, and, in particular, free flight (and hence defaecation) is inhibited. On the other hand, field experiments are notorious for being accompanied by numerous uncontrollable variables.

The experimental work I shall now describe was carried out using a small colony of bees installed in a glass-house. Whilst such conditions do not give a highly accurate control of temperature and humidity, all the disadvantages of the alternatives I referred to earlier are eliminated.

If dishes of sugar syrup are placed on a table in the glass-house their contents will soon be discovered by the worker bees and active foraging will ensue, followed by storage in the combs of the hive. A series of experiments were undertaken to measure the effect of adding certain chemicals, some of which were known insect-repellents, to this sugar solution. The object of this work was to try and evaluate the potency of certain chemicals as bee repellents, and a careful study of the results showed that the bees' response to these chemicals followed definite patterns, some of which appeared to be of interest in throwing more light on the mechanism of chemo-reception in the bee.

A series of solutions of sugar syrup containing various concentrations of phenol ranging from 0·1 per cent. to 0·000001 per cent. were made up and the responses of the honeybee to these solutions were then measured using different techniques. All the dishes used in any one experiment were arranged equidistantly on the circumference of a turn-table approximately 18 inches in diameter. The turn-table was geared to a motor via an eccentric drive which made a complete revolution in 16 minutes. Thus, the position of the dishes' relation to the hive was continuously changing. The first test is made by alternating four dishes of the sugar syrup plus repellent with four dishes of the pure syrup at the same concentration, and the effect of the repellent is assessed either by comparing the number of visits made by the bees to each set of dishes or by weighing each group of dishes after a suitable interval of time. This test amounts to providing an alternative to the test solution in space.

The next test is conducted by covering up one set of dishes for an interval of time, and then quickly changing the covers to the opposite set and leaving them on for a similar length of time.

The results of such tests with phenol reveal that the two methods of proffering the alternative of pure sucrose evoked quite distinct types of response. When the alternative is offered in time a distinct sigmoid response curve is obtained which involves a very narrow range of concentrations. The solution which is completely acceptable is 0·01 per cent. and that completely unacceptable is 0·05 per cent. When the alternative is offered in space a double response curve is obtained and the concentrations involved range from 0·05 per cent. to 0·000001 per cent. This pattern of behaviour was found with other chemicals such as acetic acid and di-methyl-phthalate.

It may be assumed that the olfactory and the common chemical sense were the main senses involved. Once a bee chose to alight on a dish she generally drank some of the solution and she was rarely seen to taste the solution with any mouth-parts, antennae or fore tarsus, although often before alighting on the dish the bee would fly backwards and forwards over the solution and at intervals it was seen to touch the surface of the liquid with one of its hind tarsi.

When the alternative of unadulterated sugar syrup is offered in space, it may be assumed that the concentrations above 0·000001 per cent. are detected by the olfactory sense organs of at least some of the bees and a proportion choose the pure sugar syrup. As the concentration increases this proportion also increases until a maximum is reached. Further progressive

increases in concentration result in a falling off of the response. This may be due to the fact that the olfactory sense organs become very quickly fatigued when exposed to this concentration or because this sense organ in the bee is specially adapted for appreciating very low concentrations of stimulants at considerable distances, e.g. flower perfumes. This fall off in response is soon terminated by further increases in the concentration of the repellent and this, it may be argued, is such that it irritates the common chemical sense of the bee. This continues until eventually at 0·05 per cent. the solution is completely repellent to all the foraging bees. This argument is strongly supported by the results obtained when the test solutions are alternated with the pure sugar syrup in time instead of space. Under these conditions there is a direct conflict between the stimulus inherent in the worker bee to collect food and the power of the chemical to act as an irritant and hence elicit an avoidance reaction. A much narrower range of concentrations is involved which still has the same concentration 0·05 per cent. as its upper limit.

This experiment using phenol was repeated using different colonies of bees at different times of the year and, although the same pattern of behaviour was always obtained, the concentration of phenol which was capable of repelling all the bees was found to fluctuate from 0·04–0·2 per cent. No definite evidence was obtained as to the reasons for this fluctuation but it was thought that it was partly determined by colony strength. The fact that the threshold of acceptance of chemicals acting as irritants fluctuates and is, apparently, dependent on the physiological state of the parent colony suggests that the stimulus for the worker bee to forage can be modified by the demands of the colony.

FIFTY YEARS OF ECONOMICS[1]

by

PROF. H. O. MEREDITH

ECONOMICS to-day is recognisably the subject I began, under the title Political Economy, in the autumn of 1899. If you should open Marshall, or J. B. Clark, or Böhm-Bawerk, you would not find yourselves in a different intellectual universe, while even the Schmollers and Sombarts, or our own Ashley and Cunningham, were economists in our sense : their dream of a new economics issuing ready armed like Athena from the head of Zeus may have faded, but only in one accidental respect has the importance of history receded : we no longer suffer from such paucity of contemporary record as made men eighty years ago turn eagerly to history to supplement deficiency of data. Whether the ratio of data to the number and urgency of problems has also risen is not, perhaps, so evident : it seems, at times, that the economic universe is expanding and that the faster we run the further we are left behind.

The standard case in economics is still what it was : a community in trade with an outside world. In this standard case, however, both outside world and community have altered and much of the difference between modern and late-Victorian economics is explicable as an attempt to adjust the subject to these alterations. Consider first the outside world. There was in the nineteenth century a long-term stable dynamic of expanding exports from industrialised areas partly to new countries which were producing reciprocal supplies of food and raw materials, partly to old where traditional handicraft goods could be displaced by machine products. Under these conditions the elasticity of international exchange and finance was so large that Marshall considered reasoning in regard to inelasticity to be an intellectual toy. Given this general presumption an economist tended inevitably to regard his outside world as a cushion, stable itself and a stabiliser for his community : he knew, and needed to know, little more about it than Mr. Podsnap's aphorism : ' Foreign nations do, as they do ! ' About his community an economist might be more curious for usually it was interest in some accident or aspect of his community which had attracted him to economic studies and one thing leads to another. Inelasticity was a working tool of some importance in community short-period problems of price or wage adjustment. But here also a seemingly stable dynamic of long-period trends cushioned the economist against over-concern with minutiae of cause and consequence. The short period might be largely neglected as not significantly affecting the long, whilst even in the longest of long runs it was only the individual, not all of us, who died : in the Marshallian forest there were no forest-fires.

The contrast with all this in our contemporary standard case is indeed remarkable. Our outside world is less a cushion than an explosive bed of Procrustes oscillating between alternate phases of rack and amputation : it is vital that we should know as much as may be about it. In our community, again, we have lost assurance of long-term trends and search painfully among short-period accelerations to discover which to encourage, which to contain. One way and another we clearly need fuller detail and more exactitude of knowledge not merely because like any other body of enquirers we wish to know more but because the nature of our problems seems to have altered, presenting us with more unknowns, demanding more equations of greater precision more elaborately arrayed.

Let us pass to a further change which

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fifty years was ago only beginning. Private enterprise had then no visible rival as a means to efficient organisation and technological advance. Now it is confronted with a formidable competitor. First Germany, then Japan, then the Ministry of Munitions, and so on to Stalin's five-year plans and such pale simulacra of planning as our own right or left intermittently entertain. Briefly the past half-century confronts us with the suggestion that centralised propaganda and discipline backed by force may achieve results which probably could not have been obtained otherwise and certainly could not have been obtained so speedily in cases where speed is essential. A key-experience was, I suggest, the failure of private enterprise in England between 1914 and 1916 with its consequences in the establishment of the Ministry of Munitions and all that went with it on both sides of the Atlantic. Had Lenin in 1920 been challenged by an English economist to say why he was so certain that Russia needed socialism he might well have answered : ' Your own recent history demonstrates its necessity : you tried private enterprise and it failed ; you switched to centralisation backed by force and it succeeded : do you blame me if, needing an even greater and swifter change-over than you in 1914 required, I follow in the path where you have led ? ' It would not have been easy, I submit, for our economist to answer effectively. He must have tried, I presume, as many of us did try, to belittle our experience, to argue that war is abnormal, that what happens in it is no guide to what is desirable when normality returns. If only ' normality ' (in that sense) could return ! It has taken some of us (I by no means exclude myself) thirty years to discover that normality (i.e., things following some line or pattern) is not a cause but a consequence or (shall I say ?) an expression of underlying equilibria, that if the equilibria which it expresses be sufficiently anarchic their normal expression will be chaos.

I have tabled these, perhaps too self-evident, generalisations because it seems to me on looking back that the course which economics has taken has not been determined solely by its own endogenous momenta but has been influenced significantly by change in its subject matter. This seems to me to be true alike in the field of observation and in the field of theory, of the transition from description to econometrics and of the shift of emphasis from statics to dynamics. But first I must say something of the great and growing demand for economics which has promoted training of economists and output of economic literature on so vastly expanded a scale. That this has not been due wholly to exogenous forces is evident if only because it began earliest and has gone farthest in the United States which finds itself still, relatively speaking, carefree at home and confident abroad. It was America that first invented and produced in significant quantity the expert in economics as opposed to the economic pundit. Nevertheless growth in the demand for economists in America no less than here has been accompanied by a shift in the kind of economics demanded. We are asked less and less to light beacons towards which courses may be set, more and more to illuminate environmental fog. Those hard-headed business men, those hard-driven civil servants, those hard-bitten politicians, who enlist our services, ask us primarily neither where to go nor how to get there but what the given situation is, what accelerations it contains, how these accelerations are reacting on one another, are increasing, or are diminishing. What they value in us at the council table is our gift for showing that one suggested course is a cul-de-sac, that another returns upon itself, that a third may conceivably lead somewhere, briefly—our power to keep the heads about the table turning until discussion has milled around sufficiently to generate some agreed decision. There is a hint of paradox in the fact that whereas when some century ago the few economists in England were esteemed authoritative their market value approximated to zero, to-day the marginal demand price for a far larger number of substantially less prestige is comfortingly high. This paradox is, however, easily resolved. Men may trust economists less but they need or at least feel that they need them more, are less certain that they know already all that economics can teach. Whether they will continue to feel this lies largely in our own hands : it is a hopeful sign that they also approach their work

to-day with a fuller sense of its difficulty, are less inclined to think little of one another and less of everybody else. The men who remind me most to-day of what economists sometimes were, are, low be it spoken, the communists : they are as irascibly cocksure that all will go well provided profit-making is abolished as Mr. Podsnap was provided it were indulged. There is, in fact, in Russia to-day a 'glad confident morning' feeling reminiscent of our own 1860's ; the language that voices it seems to echo Gladstone's paean of 'prosperity advancing by leaps and bounds.' By the same token, if I may judge from what I spell out painfully in *Ekonomiki voprosi*, their economics however structurally compact is, from our point of view, vestigial.

To take such a place at the council table as I have indicated, an economist needs to-day a more and more detailed knowledge of contemporary economic fact, a more and more elaborate theoretical insight into interaction through and across time. Where his predecessors dealt mainly with things in the round, for him the dispersion of a mass is often as important as its total. His function is no longer one of sensing overriding tendencies from some point outside the battle. He must enter the melée and submerge his mind in a welter of strategic planning and tactical manœuvre.

It would be misleading to suggest that nothing of this was sensed or surmised in 1900 or for that matter in 1870. In England, at least from the career of Jevons and the contemporary beginnings of Marshall, there was agreement among economists of every school or tendency on the need for more factual knowledge and for broader and deeper analysis. By 1900, if there was not much doing in analysis, the tide of information was rising. The Royal Commission on Labour had, as he told the world later, re-educated Marshall, Booth had organised and published his *London Survey*, Beatrice Potter had explored co-operation, the same Beatrice with Sidney Webb had delved deeply in Trade Unionism, Rowntree had turned his microscope upon the poverty of York. Nevertheless the total flow of orderly organised information was small, the technique of investigation, statistical or other, was rudimentary, the standards of economists whether in observation or in analysis was amateur rather than professional. Consider, for example, the Fiscal Controversy : seen in retrospect it is, surely, a melancholy business, wherein those arrayed on the one side do not know how to argue their case, while those on the other fail to see that there is a case to be argued. How little of all that literature has survived or deserved to survive ! Marshall's *Memorandum*, perhaps, and Pigou's *Preferential and Protective Import Duties* on the one side : on the other, Balfour's *Essay on Insular Free Trade* and Bickerdike's paper on *Incipient Import Taxes*.

The progress since those days alike in analysis and in observation is indeed stupendous. The mere quantitative increase of published economics is daunting apart from what sleeps, for security or other reasons, in the files of government offices and business houses or in unpublished dissertations on the shelves of University libraries. I have been glancing recently at the bibliographical notes in the *A.E.A. Survey of Contemporary Economics* and cannot sufficiently congratulate myself on having so long passed the age of attempting to keep up to date. And after all, what even American economists read (and their erudition has always astounded me) can be but a fraction of what there is for them to read even if they should confine themselves (as Americans by no means tend to do) to what is available in English. On this side the Atlantic also, though erudition now as ever is by us less highly esteemed, I am impressed when I meet my juniors by the dozens of books and articles which they discuss and have evidently at least glanced at as compared with the tiny number I had heard of, let alone read, when I was their age. Moreover, though I find contemporary economics less and less intelligible, I seem to sense in it an ever rising standard of professional competence. New notions are taken up and debated and after suitable dust of conflict something reasonably definite emerges : a new brick is added to our tower of Babel.

The leading part in this growth of a profession of economics has been played by America with England a good second,

and Scandinavia and Holland hard on our heels. The coming greatness of U.S.A. economics was seen by Marshall on his second visit to that country. He was impressed he said, speaking of their economists, ' not so much by the force as by the promise of force.' Germany at that time might have seemed a more likely candidate for the first place but in economics as in other matters the fatalism of German intellect, its chronic *ich kann nicht anders*, has prevented great minds from getting sufficiently together for fruitful intercourse. If any of my hearers doubt this let him cast his thought back to the great debate at Dresden in 1932 on Probleme der Wertlehre when eleven schools of thought were most competently expounded and no one listened *effectively* (the operative word) to what anybody said. On Russian economics I will say something later : here one word more on The United States. The conditions of American life from the War of Secession onwards protected their economists from that sense of the unimportance of the short period which was our bane in England. They had confidence in the future of their community, in a sense more confidence than had we, but far less feeling that how their future would shape itself was independent of what happened from day to day. And, on the other hand, what was happening was more arresting and exciting, was calling more urgently and obviously for examination and control : witness, for instance, the evolution of transport and banking and the emergence of a ' trust ' problem. Furthermore, the activity and mobility of American life, the fact that the individual graduated often through several occupations in widely separated localities before he settled down, bred a habit of mind in which it seemed natural to take stock of situations and be guided by measurement and ratiocination rather than by pressures of circumstance and tradition. Let us add that, for one reason or another, Americans are (shall I say ?) less reticent than we are, have less horror of washing linen whether dirty or clean in public, less feeling that individuals and associations have a right or a duty to keep their own counsel, to refrain from confession of weakness or boosting of success. Lastly, the American academic tradition much as it owes to Scotland and England has drawn far more than our own on European sources : there is a catholicity in American economics which we can but admire, our own tending still to smell too strongly of Cambridge, of the London School of Economics, of Glasgow, or where not.

You will not, I hope, be expecting from me a *catalogue raisonné* of this vast expansion in economics, or a detailed exposition of its star events. I shall content myself with a perhaps too personal account of ' how it strikes a contemporary ' who however incompetent to keep up with and comprehend what was going on about him yet never wholly lost interest in it and did manage to pick up some crumbs from those groaning tables. Let me begin by stating that I am constitutionally sympathetic to one of the most obviously important developments, namely our abandonment of the Marshallian doctrine that the proper place for theory is at the back of the mind, that it should make only occasional appearances on the stage to forge short links of argument, our transition to the view that it should sunbathe in the shop window with every jot and tittle exposed to full glare of publicity. I always wished for as complete a theoretical model as possible of the economic universe, one moreover that would fall into its place as part of an even wider synthesis enclosing the whole of human desire, activity, satisfaction. Such was my dream, and so was I attracted to Jevons, to J. B. Clark, to Wicksteed, to Irving Fisher, to Schumpeter, craving for a complete blue-print of the skeleton which Marshall preferred to keep, not precisely in a cupboard, but masked behind flesh of fact and apparel of tradition. I ought, it should seem, to have rejoiced as the pendulum swung over more decisively in my preferred direction, as Pigou exposed Marshall's skeleton and developed its knubblier parts into progressively more delicate articulations, as elements of Lausanne and Vienna infiltrated the London School of Economics, as more and more complicated geometry and algebra invaded the text-books, as issue after issue of the *Review of Economic Studies* and *Econometrica* slipped into their places on library shelves. I ought, I say, to have rejoiced and in a sense I have, but

my delight has been partial and embarrassed. It *is* shy-making for a professor to realise as the years go by that more and more of the new work in the subject to which he is accredited is to him unintelligible. If only I had been taught, or been able to teach myself, mathematics! I made attempts but could never reach a sufficient standard. The statement, for instance, that the number of our equations should neither exceed nor fall short of the number of our unknowns conveys as nearly as is possible, nothing to my mind. With that you might judge that I should be well advised to let the matter rest, but I have not even tried to persuade myself to do so. It seems to me too evident that the whole progress of economics during my lifetime has been bound up with mathematical talent and training. Had Marx soaked his youthful mind in mathematics instead of in Hegel his impact on the world might well have been less, but we should not still have been waiting for some indication that his majestic intuitions and ant-like industry had initiated a branch of science that was capable of growth.

Let me record, shortly, my sense of what may be gained from trying to think mathematically despite failure to acquire manipulative technique. It might seem the merest common-sense to suggest that if two forces x and y co-operate in producing a resultant z we should not expect to double z by doubling x or y while leaving its fellow unchanged. Yet how haltingly and gradually did this common-sense infiltrate economic thinking, from its beginnings in Ricardian rent theory, through the misty origins of diminishing marginal utility, and so at last to the august generalisation of the diminishing marginal productivity of individual factors! Looking back I see how my own mind, over a period of say twenty-five years, repeated a process which had taken economics say a hundred years, which is now I imagine traversed by representative students in five years, by the élite in five months, by an exceptional freak in five days. I cannot doubt that Marshall was fundamentally mistaken when he wrote: 'The chief use of pure mathematics seems to be in helping a person to write down quickly, shortly and exactly some of his thoughts for his own use': he did not realise that without his own mathematical bent and training his mind could never have formulated these thoughts precisely enough to be written whether down or up. No: there is no going back from the dictum of Jevons: 'economics deals throughout with quantities; it must be a mathematical science in matter if not in language.'

A mathematical approach must evidently stimulate interest in defining precisely concepts of national income and accumulation and in national accounting generally. It was not for nothing that Irving Fisher spoke of his work on Capital and Income as 'a kind of philosophy of economic accounting.' Briefly, mathematical economics has always in view just such a blue-print or complete model of the economic universe as I adumbrated earlier. Marshall no doubt had such a model but he kept it deliberately in the background and it was not until I read Pigou's review in 1907 of a new edition of the *Principles* that I realised, or thought I ought to try to realise, the cardinal role of the national dividend concept in that great work. My own readings of the *Principles* had left me uncomfortably vague as to what was and what was not income whether national or individual and it was Irving Fisher and Pigou who did most to clear up my perplexities. I have never quite got to the end of them and some not too recent suggestions of Professor Hicks have opened new vistas of uncertainty. I used to think and teach that Adam Smith's distinction between productive and unproductive labour was sheer muddle, but I now suspect that as in the somewhat analogous case of Marx's theory of value there may have been a real problem behind an unconvincing solution.

Concern for precise formulation measurement and sub-division of the national dividend has played a notable part in the evolution of theory. Unless we conceive of it as a quantitative magnitude, as long as we think of it vaguely as an emanation from similarly misty aggregates of productive forces it is not easy to proceed to the notion of the part played by amount and composition of the national dividend at one moment in shaping its amount and composition at the next. A door to that development was opened by Keynes in the

Treatise when he formulated his first equation in terms of total output savings and investment, deriving from it a definite sum of positive or negative profit encouraging or discouraging increase of total output. Doubtless at that time Keynes was thinking mainly of price levels and fluctuations and was only at the beginning of the train which led to his General Theory. Nevertheless the link of implication seems to be clear as also the dependence of the whole catena on a mathematical approach.

I am concerned to emphasise this point because it connects the whole movement in economics for which the name of Keynes has become a symbol with the prodigious pioneering of Irving Fisher—the greatest name, if a foreigner may presume to judge, in American economics. He takes us back, of course, some twenty years before my period but his work from the very outset and his whole approach to the subject were essentially modern. The pioneer treatise on mathematical economics, the pioneer model mechanism for exhibiting theory, the treatises on capital and income, on interest, on the purchasing power of money, the ' Grand Old Man ' of the econometric society, the man incidentally who in a college text-book twenty years before Keynes' *General Theory* insisted that the study of value is inseparable from the study of money. Keynes, I feel, was less a professional economist than a superman whose orbit happened to intersect our pedestrian proceedings. Neither the *Treatise* nor the *General Theory* shows either the erudition or the thorough grounding of a professional however truly each of them towers above such standards in freshness and force and forensic ability. It was, in fact, largely because he was not an economist or, as I personally should prefer to put it, because he was so much more than an economist, that his impact on the subject was so important. Coming from outside us, but speaking sufficiently our language, he gathered eclectically what was serviceable to his purpose and, throwing what he gathered into what Bloomsbury would have called ' significant form,' at once inspired and focused debate. It is this peculiarity in his work which justifies common use of such a term as ' the Keynesian revolution ' for an advance in economics which has embodied the work of numerous writers in many countries and was not due to or even predominantly inspired and directed by any one man.

I pass to another movement which is even more difficult for a non-mathematician to grasp and delineate, namely the shift of emphasis from static to dynamic theory. What I seem to see here is not that problems which used to be regarded as dynamic have risen in importance relatively to those which were aligned to statics but that the nature of what was treated by statics has so altered as to demand dynamic treatment, while much of what was regarded as dynamic has dropped out of the picture for the time being. It cannot, I suggest, be accidental that contemporary dynamics contains so little reference to the work of Marshall and J. B. Clark though the former professed a dynamic economics *pur sang* while the latter restricted statics to short period problems. If we enquired after the origins of modern dynamics we should be led back, I think, primarily to Wicksel, behind him conceivably to Sombart and Böhm-Bawerk, behind them to Marx. It may however be doubted whether these or other possible lines of development are worth examining : it seems more probable that our modern movement has sprung from those changes in the economic universe which I sketched in my introduction. Marshall, it will be remembered, deprecated the importance of J. B. Clark's distinction between static and dynamic problems, arguing that dynamic theory is inclusive of statical as the special case where accelerations are reduced to zero. It might have been retorted that he himself kept his accelerations so low that his dynamic theory differed but little from a static and there may well, I imagine, be readers of Marshall who tend to think and speak of his work as statical, forgetful that in his own view the billiard balls and the basin were slowly, slowly, oh so slowly, changing shapes and sizes and shifting ever so slowly this way and that. It may be noted also that in his biological analogies Marshall was eminently of the older Darwinian school, was thinking of the accumulation of infinitesimal changes through epochs of geological time. *Natura non facit saltum* was his motto, on

which Schumpeter remarked aptly some forty years ago, in accordance with neo-Darwinism, that evolution *gerade zu sprungweise fortgeht.* Clark again in his dynamics was not, I submit, a modern, however important his work may have been in clearing the way. For him dynamics found its field in the long period, to the short statics were appropriate. Why? Surely because he, equally with Marshall, believed that short period oscillations in the main cancel out and are of negligible importance in the long run. May it not be that it is because this view seems no longer to be tenable that economists more and more find it necessary to include accelerations and acceleration of accelerations in *all* their work with the result that theory is from top to bottom more and more dynamic and by the same token constrained to briefer and briefer time periods through the increasing difficulty of predicating anything with certainty about the remoter future?

This brings us to the threshold of the high theme of econometrics, if I am right in supposing that econometrists aim to clear economics of equations based upon psychological postulates and to found it upon direct inductions from objectively observable and measurable phenomena. This movement has done something and there is good ground for hoping that it will do much: it may be useful, however, to define a difficulty which it, in common with all other schools, has, whether at the outset or ultimately, to face. If economic consequence worked itself out wholly in the economic field as physical seems to do in the physical, the road to a perfectly objective science of economics would be open. The facts, however, seem to be otherwise. It is generally agreed that part of the causation and part of the consequence of every economic event occurs in the non-economic field, but not all of us draw the inference that the whole of economic consequence of an economic event cannot be ascertained by a purely economic calculus. The economic consequence will always include a repercussion-element mediated back from the non-economic into the economic field: for complete accounting, therefore, even of economic consequence only, a calculus which covered both fields would be necessary. In so far as such reactions are important, and it is probable that in some critical connections they are very important, economics must remain an art and cannot become science, must rely not on measurement and reasoning but on judgment and intuition.

There is much else I should like to speak of, there are many names I should like to mention, in what may well be my last at all formal utterance on economics; but what I have said may have suggested all too sufficiently the kind of things I might have said, had time permitted, on other relevant topics. I shall conclude by offering a few remarks on a very vexed question —namely, that increasing difficulty of economics, which, however it may attract us by challenging our powers, yet also occasions most of us at one time or another more than one kind of head- or heart-ache. Speaking with all due humility it does seem to me a pity that so able a man as myself should have found so much of the subject beyond his power of comprehension: yet I have felt obligated to state what seems to me a convincing defence of its increased and increasing complexity. This would not matter if the problems with which it deals were such as the average man can safely leave to wiser heads than his. Economics is a socio-political subject and if the nit-wit abandons it to the wise-acre each of them will ultimately find himself in the cart. Is there any hope of escape from this dilemma? There may be some here who remember twenty-five years ago a plea for simpler economics addressed by Edwin Cannan to the Royal Economic Society. It was a moving plea, but it has not stayed the march of complication. Cannan could see things simply because he was in the best sense a simple soul with clear-cut convictions and unwavering faith. We, by comparison, have divided souls, have been told that in the long run we are all dead, have more than a suspicion that our apple-cart may be overturned before the long run arrives. It is this creeping fog of doubt and sense of immediate urgency which involves us in more and more elaborately difficult effort to measure in detail our day-to-day environment, the direction in which each part of it is moving, its speed of movement. Briefly, if we want (and we

ought to want) to simplify economics we must begin by simplifying life. I do not mean that we should strive to become 'simple lifers' in the escapist sense of denying life in order to avoid its perplexities, but by a real process of restoring men's faith in the long run and giving them better grounds for it. It may well be that economics has a part to play here in the next fifty years no less important than the honourable if modest part it has played during my working life in the gestation of the Welfare State. If society can assume a form in which problems of day-to-day adjustment are less acute it will matter less what precise adjustment is reached in particular cases: rougher observations and cruder theories will suffice: there will be less need for ultra refinement. Unfortunately it is all too easy to confuse ease of adjustment with enhanced power to thrust the weaker to the wall or less resistance on the part of the weaker to going there. And further it is not sufficient to set up true valuations: they will not operate satisfactorily unless they are felt to be true. There is, none the less, some hope in the paradox that in a world where everyone valued everything correctly and felt that it was so valued there would be no need of a theory of value. We need economics the more the more current valuations are or seem to be unsatisfactory. Doubtless it is for this reason that economics are (from our point of view) vestigial in Russia, the *communis opinio* there, or what passes for it, feels that current valuations are broadly speaking so right, or so little wrong, as to leave little room for argument and little need for elaboration of observation or theory to support argument. Difficulties and disputes there must no doubt be but—*solvuntur ambulando*.' This state is admittedly the outcome of a centralised power, a systematised propaganda, a ruthless official discipline, beyond everything which we experienced in either war. It is claimed, on the other hand, that representative Russians are less frightened of Stalin than they are of private enterprise, and knowing what one does of Russian conditions before and since the revolution it would not surprise one if this claim were justified. What concerns my discussion more is the fact (as it seems to me to be) that Russia has developed a will to work in a disciplined way, a flexibility of economic organisation, and an enthusiasm for technological advance, which have enabled her not merely to make a creditable appearance at Helsinki but to carry through an economic metamorphosis incomparably greater and swifter than history can show elsewhere. The nearest parallel perhaps to the Lenin-Stalin episode is the career of Mahomet. He had their power of propagating split-atom mass enthusiasm, but his problems of reorganisation were not fundamentally economic. Some comparable degree of simplification might be forced upon us swiftly by some adequately disastrous emergency as it was forced upon Russia by the inability of Czarism to meet the German challenge. Without such compulsion we cannot, or at any rate men of my age cannot, reasonably choose to do more than move towards it by such gradual changes as will leave us feeling free. The Welfare State, we may hope, is a first step in the right direction, attacking some of the most menacing of our inelasticities, but much more will be needed before it will be possible for us to feel like St. Paul that a new discipline has begotten a new and larger liberty. Until that transition is accomplished I am afraid that economics must continue to be difficult and that economists must expect to hear men mouth against them intermittently the jibe of the poet:

'They use the snaffle and the curb all right,
But where's the bloody horse?'

THE HISTORY OF THE IRISH FLORA AND FAUNA

by

PROF. J. K. CHARLESWORTH

AT the Belfast Meeting of the British Association a joint session of sections C (Geology), D (Zoology) and K (Botany) on September 9, 1952, was devoted to consideration of the History of the Irish Flora and Fauna. Professor J. K. Charlesworth, Queen's University, Belfast, described the general physical conditions of the glacial period in Ireland ; Dr. A. Farrington, Royal Irish Academy, Dublin, emphasised the probability of an extensive ice-free strip off the western coast and of smaller refuges between the ice-sheets ; Mr. G. F. Mitchell, Trinity College, Dublin, traced the immigration of the plants into the country in late glacial time ; and Dr. J. Heslop Harrison, University College, London, justified the assumption that the Irish floral history can be reconstructed exclusively from the modern plants and their anomalies. Professor Charlesworth has edited the four papers.

THE PHYSICAL CONDITIONS OF THE GLACIAL PERIOD IN IRELAND

by

Professor J. K. Charlesworth

THE Irish flora and fauna have four distinctive features, namely, their poverty and their arctic-alpine or arctic-montane, Lusitanian - Mediterranean and North American 'elements.' Ireland has, for example, only about 60 per cent. of the flora of Great Britain, 35 out of the 50 mammals and 326 of the 520 birds. In this respect, Ireland exemplifies an island flora and fauna. The arctic-montane element presents no difficulty : it came with and survived the glacial period. The main problem concerns the Lusitanian and North American elements, i.e. the species which to-day are found in Portugal or the Mediterranean region, and a few North American plants, snails, insects, woodlice and earthworms. These two elements may have survived the glacial period or may have come in late—glacially or postglacially, either over land-bridges from Great Britain or by accidental dispersal, i.e. by winds, currents, birds or man. Any species which survived the glacial period must have lived in Ireland a very long time since the Bay of Biscay is an old feature in the map of Europe, and the weight of evidence suggests that a land-bridge with North America over Iceland and Greenland was preglacial.

At the Meeting of the British Association at Portsmouth in 1911 the problem of the Irish fauna and flora was discussed and the two views just mentioned were defended.[1] Since that date two facts have emerged more clearly, first, the importance of interglacial periods, secondly, the severity of the glacial climate outside the ice-sheets. Both facts have a vital bearing on the problem.

The occurrence of one interglacial epoch has been positively established as has the probability that there were two others. The middle one of these three—the 'great interglacial '—was not only warmer than the present but lasted a long time. Ireland could have had little or no ice at the time when the mammoth, a Pleistocene animal whose teeth have been found in several places in the county, lived in Co. Antrim.

The polyglacial theory has two important consequences, one in space, the other in time. While on the monoglacial view the country was covered to the limit

[1] Report, British Assoc. 1911, pp. 573–80.

of the drift at one and the same time, on the polyglacial view it was covered at different times and ice-free areas existed which were not necessarily always the same areas. This is obviously important if it can be proved. The second effect has perhaps greater significance. While postglacial time is probably about 20,000 years, the great interglacial period lasted roughly a quarter or half a million years, i.e. 12 to 25 times the period during which life has spread postglacially. It is not surprising, therefore, that in Scandinavia and eastern North America where a similar problem exists, those who favour survival postulate a survival not through the whole glacial period but through the last glaciation only. In this way the two opposing views of extermination and survival are largely reconciled.

The climatic conditions during the glaciations were severe. Life, unable to persist under the ice, may have survived on mountain summits (' nunataks ') projecting above the ice, on lowlands outside the ice, and on the exposed ocean floor. The small area, great altitude and severe frost of the nunataks, if any such existed, must have been inimical to life. The ice-free lowlands were likewise subject to severe physical and climatic conditions : true soils and humus were absent ; the ground was permanently frozen and in summer was liable to solifluction even on gentle slopes ; hillsides were covered with unstable scree so that plants found it difficult to secure a foothold ; cold winds blew from the glaciers and cold meltwaters proceeded from the ice and constantly changed their position. Life on the exposed ocean floor, between the ice-edge and the lowered sea-level, suffered from these conditions as well as from the salinity of the ocean muds and sands.

Whether life could have persisted in these three kinds of habitat it is not for a geologist to say. It is however highly probable or even certain that some of the localities where the species now occur are not the original places of survival ; that some life immigrated postglacially at the time of the ' buried forests ' over a land-bridge with Scotland over Islay, and possibly, to the Dublin area from Wales ; and that other life gained by access by accidental dispersal including the action of man.

Glacial Refuges off the West Coast and within the Country

by

Dr. A. Farrington

Survival of the preglacial life was possible in Ireland because the main ice-sheets which flowed from the north-west and the north-east and covered most of the country were separate from the ice of the south which spread from an independent centre over the counties of Cork and Kerry. During the last glaciation the ice of the ' Newer Drift ' or the Midland General Glaciation extended southwards to the South Irish End-moraine which follows a sinuous line from near Wexford by the Dublin Hills to the mouth of the Shannon. South of this line local ice-centres existed, the chief of which lay in the south-west. At this time, as is generally recognised, there was ample room for the survival of both animals and plants.

At an earlier and more critical stage (Eastern General Glaciation), the northern ice was more extensive. It spread to a line which ran from the Dingle peninsula on the west round the northern slopes of the Mullaghareirk and the Nagles mountains to the mouth of Cork Harbour. The local ice in Cork and Kerry was also more extensive but it came somewhat later. Thus wherever sections can be examined, the Cork-Kerry drift, which is a reddish, sandy boulder-clay derived in the main from the Old Red Sandstone, is seen to overlie the brownish, calcareous boulder-clay of the Eastern General Glaciation, with its far-travelled erratics. In Ballycotton Bay, Co. Cork, for example, the Cork–Kerry drift, 7–8 feet thick, rests upon a layer of sand, about 15 feet in thickness, which overlies and was derived from an eroded surface of the lower clay. Between the northern and southern ice-masses, thus proved to be not strictly contemporaneous, life could have persisted. This was especially true on the small refuges which extended along a line from Dingle Bay to the estuary of the River Blackwater and which were favourably situated on south-facing slopes.

Field-work now in progress indicates that small ice-free areas occurred in the west, including the western part of Achill

Island in Co. Mayo. The inference from this is that the ice-sheet there was of no great thickness, a conclusion supported by evidence found near the western coast of Co. Kerry where at the maximum of the Cork-Kerry glaciation the ice was only 300 or 400 feet thick. Over much of its length in the west, the ice probably advanced only a short distance beyond the present coast. Hence, with a low glacial sea-level, there may have been a very extensive offshore asylum.

Heavy precipitation rather than very low temperatures was probably the chief factor in the glaciation of Ireland. The long glaciers which streamed from small gathering grounds, the length of comparatively shallow glaciers and the progressively lower level of the corries towards the south-west all point to this conclusion. Hence the climate in these latitudes was probably not so rigorous as has commonly been assumed and should not be compared with that of the present arctic. On the contrary, the glacial period in Ireland was comparatively mild and tempered by moisture-bearing winds from the west.

The Immigration of Flora and Fauna into Ireland in Late Glacial Time

by

G. F. Mitchell

Early Pleistocene floras (e.g. the Cromer Forest Bed) are very similar to those of to-day. Advances and retreats of the ice-sheets moved plants about, like pieces on a chessboard, but did not produce any basic changes in the composition of the flora.

The last main advance of ice to the South Irish End-moraine (probably Würm in age) was smaller than the advances that had preceded it. At the time of the South Irish End-moraine frost acted severely on the ice-free areas further south and conditions were probably difficult for most forms of life. Late-glacial time began when this ice began to recede.

This time can be divided into three zones or stages. The first covers the retreat of the ice from this moraine to a point behind the moraines of the Antrim Coastal Re-advance, i.e. until Ireland was completely free of ice. The only fossiliferous deposits known are lacustrine clays from which the remains of eight plants only have been recovered. While (on the mainland of Europe to-day) *Empetrum nigrum* does not live beyond 63° N., the other seven, *Astragalus alpinus*, *Isoetes lacustris*, *Myriophyllum alterniflorum*, *Potamogeton praelongus*, *Ranunculus aquatilis* s.l., *Rumex acetosella* agg. and *Salix herbacea*, all reach to 70° N. or the North Cape itself.

The second zone, the Alleröd stage, was a period of genial climate throughout north-west Europe, and plants migrated on a great scale, presumably from the south. Fossil remains of eighty plants, and also of *Cervus giganteus* and *Rangifer tarandus*, have been obtained from the muds of this zone.

In the third zone climate again became more severe—in Scandinavia the ice advanced to the line of the Ra and the Salpausselkä moraines. Ice formed again on the mountains of Scotland, Ireland and Wales and minor solifluction took place on the lowlands of the British Isles, In Ireland the solifluction earths have yielded the remains of a further thirty-five plants : the remains of mammoth from Drumurcher, Co. Monaghan, may also belong to this zone. When the climate became warmer again trees and forest mammals advanced into the area and the late-glacial period was ended.

A detailed list of late-glacial plant fossils shows that the northern plants of the modern Irish flora (the arctic-alpine or montane element) are well represented in it, e.g. *Draba incana*, *Dryas octopetala*, *Oxyria digyna*, *Salix herbacea*, *Saxifraga oppositifolia* and *Thalictrum alpinum*. It includes some plants which no longer grow in Ireland, though they do maintain a precarious foothold in Great Britain, e.g. *Astragalus alpinus*, *Luzula spicata* and *Minuartia stricta*. The northern forms that still live in Ireland are the survivors of a large group of arctic-montane plants that made their most recent entry in late glacial time. *Lepus timidus* has the same status.

The list also has several plants of southern affinities, including some of the Labiatae, a family which is rare in arctic regions. There are Irish late-glacial records for *Clinopodium vulgare* and *Lycopus europaeus*, which in Europe to-day do not

extend further north than 64° N., and for *Acinos arvensis* which nearly reaches the Arctic Circle. The conclusion therefore is unavoidable that in late-glacial time a large number of plants (and presumably of animals too) entered Ireland from the south, and that in view of the southern forms among them the rate of migration was probably a more important factor than climate.

Of the 250 plants identified by K. Jessen and G. F. Mitchell from Irish late glacial and postglacial deposits, 123 or about 50 per cent. came from the late glacial deposits. Thus there must have been great possibilities for migration before the postglacial forests were established. The Lusitanian element in the modern Irish flora and fauna probably entered during this migration period. Of the American element which was probably present in the preglacial flora of north-west Europe, few survived the forced marches of the glacial period.

The Modern Distributions of Irish Plants in the Light of Postglacial History

by

Dr. J. Heslop Harrison

Recent investigations of Irish quaternary deposits have brought to light new data which make it necessary to reconsider the formerly widely held view that details of the history of the flora can be deduced from modern distributions. The findings of Jessen (1) and others tend to demolish certain theories of the history of the biota put forward to explain present distributions, and those remaining must clearly be pressed only with the greatest of caution. The common procedure of defining floristic ' elements,' i.e. grouping together species because of some particular distributional peculiarity which they happen to have in common, offers opportunities for misrepresentation and misinterpretation when carried out on a small scale, as when dealing with the Irish flora. Firstly, there is the possibility that elements thus defined may be in no sense homogeneous, the local coincidence in area being purely fortuitous, resulting from the chances of dispersal. On the other hand, in attempting to introduce homogeneity, elements may be circumscribed too closely, and the fact thus obscured that the species concerned are merely the extreme examples of a series of distributional types which in reality leads back through intermediate patterns to one which itself is more easily understood. Stapf (2) and Matthews (3) have emphasised this point in connection with the Irish ' Lusitanian ' plants. Then, the unity of a particular element may be due to currently acting ecological factors, and where such is the case, propounding historical explanations for disjunct distributions may be superfluous. The practice of looking at outline maps with species distributions entered upon them invites error in this connection by eliminating from consideration contemporary causative factors which may be responsible for at least the negative aspects of distributional patterns. Finally, if contemporary ecological factors cannot account for the distribution of a geographical element, and if the possibility of recent arrival of its components can be dismissed so that an explanation for it must be sought in historical events, it is important to accept that there is no justification for going back further in time than the latest such event which could account for what is observed.

The so-called arctic and arctic-alpine elements illustrate these points. Some botanists have asserted that these have survived a glacial episode (or even the entire glacial period) on nunataks. But some of the plants concerned are now known to have been widespread in Britain during late-glacial time, even in the lowlands. It is therefore both illogical and unnecessary to suggest that the present centres of these species represent areas where they survived a glacial period. They are rather centres where survival through postglacial forest phases was possible, and are ' forest,' not ' ice ' refuges. These species are to be interpreted in relation to modern habitat conditions, e.g. the availability of appropriate substratum (many are calcicolous), low summer maximum temperature, and freedom from competition, and to the same factors] throughout postglacial time. The present habitats are, for most of the species, immature ones, with undeveloped,

generally unstable soils, bearing immature and usually open plant communities. Many can confidently be said to have been the same throughout postglacial time. Thus *Salix herbacea*, *Dryas octopetala* and *Silene acaulis* live to-day on the basalt scarps of north-east Ireland, that is, in habitats of a markedly open nature, mostly north-facing cliffs of crumbling basalt. The areas of the surviving representatives of the late-glacial flora were probably much contracted as a result of the pressure of competition during the climatic optimum, and there are indications that some of them have passed their postglacial crisis, and are now in the process of limited re-expansion.

The plants forming the N. American element in the Irish flora are of interest *not* because they have N. American ranges (quite a high percentage of British plants other than these have natural ranges on the other side of the Atlantic Ocean) but because they have very limited ranges *in Europe* entirely within the formerly glaciated area. In N. America, where they have extensive ranges, they have been able to follow up the retreat of the ice. The question is, why have they not done so in Europe if indeed they survived a glacial period here? Climatic limitation can hardly be invoked as an explanation when the extent of the American areas is considered, and in any case, the biotypes of species like *Ericaulon septangulare* are well enough adapted to conditions here to be able to reproduce freely and establish themselves often in almost pure communities. Their whole behaviour as well as their present limited ranges would be quite consistent with a hypothesis of recent arrival. The Greenland White-fronted Goose, *Anser albifrons flavicornis* (suggested first in this connection by Mr. Sullivan, an Irish lighthouse keeper) is a possible agent of dispersal. The main flock of this bird breeds in north-western Greenland and winters in Ireland; some part of the Greenland population may also winter about the mouth of the St. Lawrence, which is the regular habit of other goose species breeding in the same parts of Greenland. These geese are large birds, frequenting lake-margin habitats and feeding largely on water-weeds. Significantly, the plants of the Irish N. American element are all freshwater species or occur here in lake-margin habitats. Some of them are known to be dispersed through the agency of water-fowl in America; and one of the species, namely *Sisyrhinchium angustifolium*, grows in north-western Greenland within the breeding ground of the Greenland White-fronted Goose.

The so-called Lusitanian element appears to provide an illustration of how phytogeographical problems can be created and their solution obscured simultaneously by the deliberate selection of a group of species with highly fragmented ranges. Though E. Forbes suggested that the distribution of these species demands an historical explanation, other questions need to be answered. These are—what contemporary factors, if any, restrict their ranges in the British Isles, and do the present ranges represent the postglacial maximum or were they formerly more extensive? If the latter, when was that period of greater expansion, and how do the probable ranges then bear on the route and time of immigration?

Regarding the contemporary areas of these species, much is to be learned by looking at the Scandinavian flora, where many species have extensions up the Atlantic seaboard of Norway into latitudes far north of the main range of the species in Europe. For example, the Irish heaths, *Erica mackaiana*, *E. mediterranea* and *Daboecia polifolia* can be matched in Norway by *Erica tetralix* and *E. cinerea*, and the Lusitanian saxifrages by such plants as *Chrysosplenium oppositifolium* and *Primula vulgaris*. Some of the area disjunctions shown by these plants are almost as great as those of the Irish Lusitanians—for example, *Erica cinerea* has a narrow strip along the western Norwegian coast which is separated from the main European range of the species by almost as great a distance as that which separates the Irish *Arbutus unedo* from that in northern France.

The limitation of the heaths and other species to these western strips in Scandinavia is accepted as being climatic and associated with the well-known trend of winter isotherms there. *Holcus lanatus* and *H. mollis* and the common heath rush *Juncus squarrosus* provide less extreme

examples. Similarly in the British flora, less extreme forms of the type of distribution exemplified by the Lusitanian species are plentiful: an interesting contrast, drawn by Stapf many years ago, is between the areas of *Rubia peregrina* (which has never found its way into a list of the Lusitanians) and *Arbutus unedo*.

As in Scandinavia, the northward trend up the west of the British Isles of various southern species can be associated with the trend of winter isotherms. There is a need for more accurate data on the microclimates in which some of the critical species grow to clinch the case, but such studies as that of Sealy (4) on *Arbutus unedo* tend to suggest that all of the classical group of Lusitanians will prove to be climatically limited.

The obvious possibility therefore exists that these species had much wider ranges during the postglacial climatic optimum. After all, knowledge of the climatic optimum is based upon just such data—northward and eastward extensions of plants and animals now known to be limited to southern areas by climate. The areas of many Lusitanian species, now severely limited, might then have looked like that of *Rubia peregrina*. Their distributions would have attracted little notice from a botanist living in the climatic optimum for his attention might have been caught by other species, possessing at that time only limited areas in the British Isles, and now totally extinct here, as indeed some of our present group of southern species, like *Otanthus maritimus* and *Euphorbia peplis*, are promising shortly to become.

About the time and route of arrival of the southern species, there can still be only speculation. The key to the problem probably lies in the answers to the following questions: (i) How quickly after the final dissolution of the ice did the extreme western seaboard of Europe become available for colonisation by species which required relatively warm winters and were not severely limited by cool summers? (ii) How long after these conditions were established did a coastline not broken by more than, say, the mouths of large rivers extend from the region of Brittany to south-western Ireland, perhaps near the level of the present 50 fathom line? (iii) How quickly can plants like those which compose the Lusitanian group expand their ranges, by normal dispersal means, into virgin areas in which communities are immature and habitats open?

There is no reason to believe that the influence of the Atlantic was any less marked in late glacial and early postglacial times in producing the north–south trend of winter isotherms along the western European seaboard. Because of this, the simple idea of a 'wave' of climatic improvement moving northward and continuously limiting plant migration has no meaning, for while the summer isotherms may have moved northward, the winter isotherms would tend to move eastwards. If, at this time, the full extent of postglacial resubmergence had not taken place, a coastline unbroken except by the mouths of large rivers extending from France to southern Ireland might well have been available. If, indeed, the winter isotherms ran north–south, a narrow fringe with relatively frost-free winters may have very quickly become available throughout and have provided the migration route northwards from the Lusitanian refuges of a whole assemblage of winter-warmth-loving species. The classical 'Lusitanian' group would then represent merely those whose area has subsequently become most fragmented by land-submergence, climatic deterioration and competition from the better adapted plants which arrived later, probably along a more easterly route.

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PROBLEMS OF THE SMALL FARM

SECTION M (Agriculture), at the Belfast Meeting, devoted a session on the morning of Monday, September 8, 1952, to problems of the small farm. Mr. R. Ede, Agricultural Attaché in Copenhagen, surveyed the problems of the small farm in Denmark. His paper is printed below. Other invited contributions to this session came from Mr. A. Cromie, who gave an account of a small mixed farm in Northern Ireland, and from Mr. W. H. Cashmore who suggested, in a paper entitled the ' Engineering problems of the small farm,' how the mechanisation of the small farm may be extended by a closer co-ordination between implement design and farm management.

SMALL FARMS IN DENMARK

by

R. Ede

DENMARK may well be regarded as a textbook for the student of smallholdings. Out of a total number of 204,000 farms, no fewer than 110,000 are below ten hectares or twenty-five acres, and in contrast to many European countries, the State in Denmark is still promoting legislation for the creation of more smallholdings. It is important, at the outset, to realise that a smallholder in Denmark differs from the peasant proprietor found so extensively in Europe. The smallholding in Denmark has for many years been regarded as an economic unit of production and not as a piece of land to be used for subsistence farming. Thus, the basic problem to-day of the Danish smallholder is how to produce butter, bacon, and eggs at a price which can compete on the world market.

The first legislation providing for smallholdings in Denmark was mainly concerned with part-time holdings which were encouraged by the larger scale farmers as a means of keeping labour on the land. Early in this century, however, with the advent of a Liberal Government in Denmark, and the opening up of an export trade in animal products, the emphasis shifted to full-time smallholdings with enough land to enable the owner to make a living. All subsequent legislation has kept this objective in view. Thus the major problem of the modern smallholding in Denmark can be summed up in the question : ' How much land is required to make the holding economically independent ? ' Coupled with this economic aspect of the problem are certain social, political and organisational questions.

Land for Smallholdings

The Enclosure Movement in Denmark in the eighteenth century was carefully controlled by legislation which protected existing copyholds and prohibited their alteration or their merging, and measures were introduced to facilitate the transference of copyholds to freehold ownership. Even at this early stage loans were made by the State or by the lords of the manors to enable the copyholder to buy the freehold. Thus Denmark emerged from the Enclosure Movement with its system of family farms intact. The unit was further preserved by legislation which prevented the sub-division of family farms below a certain size. More recent legislation prohibits the merging of farms as well as maintaining the minimum area to which a property may be reduced. The present minimum is two hectares (five acres) and the problem of merging is further controlled by the fact that it is illegal for one man to farm two smallholdings which are less than five kilometres (about three miles) apart. Anyone owning two farms below twenty-five acres within a distance of less than five kilometres is obliged to let one of the farms for at least eight years.

The first Land Settlement Act under which the Government assumed the responsibility for providing land for smallholdings was passed in 1899 and dealt

with part-time holdings of two to three hectares (five to seven-and-a-half acres). This was amended in 1906 with the object of buying land and creating larger and economically independent holdings. Subsidies for the establishment of smallholdings were given to Land Settlement Societies which had been formed by existing smallholders themselves for this purpose. This acted as a valuable check on private speculation in land settlement.

All the holdings under the Act of 1899 were freehold, but in 1919 a new principle of land settlement was adopted. In that year all entailed estates were abolished and they had to surrender one-third of their land to the State against compensation. This has been used to create smallholdings, but the holder of the land does not buy the land, but pays a rent based on its value which is re-assessed every five years according to the state of agriculture. The farm can pass to the owner's next of kin and can be sold, with State permission. The holders own the buildings and the live and dead stock, but the land is a form of inheritable copyhold.

It is only natural that those interested in large scale farming are not wholeheartedly in favour of the further creation of smallholdings. They point out that for the past twelve years the larger farms, which can grow cereals, have contributed a very large share of the feeding stuffs needed by the smallholder. Cereals have for most of the period been subject to compulsory delivery at fixed prices and a proportion of these deliveries have been earmarked at a special price for the smallholder on less than twenty-five acres so that he could maintain his livestock production. In commenting on the survey figures mentioned earlier the association of large scale farmers point out that if the development toward the typical smallholding continues, the country may find itself in a dangerous state of dependence on imported feeds with no large scale farmers left to grow the cereals in Denmark.

A suggestion often put forward is that the smallholder on a constricted piece of land should develop an even more intensive system of farming such as market gardening. Whilst this may be a possible solution for smallholders near the towns it is not practicable for general application. Denmark must export agricultural produce to live, and her climatic conditions and geographical position do not lend themselves to vegetable exports. Fruit growing, especially apples, is on the increase, but requires too much capital and too long a period of establishment to offer much relief to a constricted smallholder.

Thus the problem of the Danish smallholder in respect of land consists of three parts : the acquisition of land for more smallholdings, the acquisition of land to increase the size of existing smallholdings, and the more intensive utilisation of the land when used as a smallholding. Efforts to solve the first two are made by legislation, but the third part needs a radical change in the traditional thinking of the Danish smallholder.

One source of additional land for farming in Denmark comes from the reclamation of heathland which over the last seventy years has provided an additional 835,000 acres of land for agriculture and this has more than compensated for the area lost to building, roads, railways, playing fields, etc., which, during the same period, amounted to 581,000 acres. Much of this land is of poor quality and the average size of farm created is about fifty acres. The interest of heathland to the smallholder is that he can reclaim land on his own initiative and receive a subsidy of about thirty shillings an acre for a yearly area of about eight acres. This is one method of allowing a smallholder access to more land.

Administration

The administration of the smallholdings laws is decentralised and the country is divided into eleven districts, each of which has a three-man committee—one member of the State Land Committee appointed by the Ministry of Agriculture, one local member of the Agricultural Society, and one local smallholder. This committee selects prospective smallholders and arranges the necessary formalities with the central administration. The official rules say that an applicant must be of age, but not over fifty-five, a Danish citizen, sober, honest, and able to manage a farm and have the necessary means. The amount of money expected of a prospective smallholder varies between

£250 and £500. More emphasis is being put on education both theoretical and practical and a five months' course at a smallholders' school, while not essential, is now one of the factors taken into consideration.

Capital

In the matter of capital the Danish smallholder is in a most fortunate position as Denmark possesses a very adequate system of credit. There are many types of loan obtained from different sources with varying terms of repayment. For a man who wishes to buy land on the free market and does not become a State copyholder, there are purchase loans up to a maximum of £800. When an estate is being subdivided into smallholdings all purchasers are called together by the Ministry of Agriculture so that architects and other experts can describe the different types of buildings available and the smallholders can make their choice. The Ministry of Agriculture fixes the maximum building loans every year and the present maximum for the smallest farms is £2,000. Very generous terms are granted for these loans, and 60 per cent. is free of interest, and 20 per cent. need not be repaid but remains as a frozen mortgage for twenty years. For the first five years no instalments need be paid on the building loan and thereafter, 40 per cent. of the total loan is repaid at the rate of 0·8 per cent. per year. The interest on both purchase and building loans varies according to the state of the money market. There is a loan for electricity installation up to £100 at 4 per cent., and repayable over twenty years. A further 'Establishment Loan' up to a maximum of £250 is available of which half is interest free and the balance is charged at 4 per cent. There is no repayment for the first two years, but after that instalments of one-twentieth of the whole loan have to be paid every half-year. There is also a fund to assist in the purchase of large animals limited to £10 per animal for not more than five animals. This loan is to prevent the new smallholder from having to obtain merchant credit. Thus a prospective smallholder with £250–£500 can obtain loans up to a maximum of £3,200. Generous loans are also available for the special equipment of market gardens and fruit farms.

Figures are published from time to time on the indebtedness of the Danish farmer and the latest figures show that the average debt per farmer is about £1,300. It is often a matter of some surprise that after a period of relative prosperity in farming the average indebtedness should be so high. But the Danish farmer is never anxious to pay off his debt and prefers to invest any surplus he may have in a Savings Bank after providing for working capital for expansions. One reason for this is that it is much easier to sell a farm with mortgages than one which is free. The purchaser can take over the existing mortgages and need not find either the ready money or arrange his own mortgages. The money in the Savings Bank is also more readily available in case of a bad year than if it had been used to repay a mortgage.

Labour

As might be expected, most of the labour on Danish smallholdings is family labour. But smallholdings are not large enough to provide employment for the sons of the family. Those who wish to remain in agriculture can, from about the age of sixteen, obtain employment with board and lodging on large farms and may in time return to take over the family holding. The other sons must remain as paid workers until such time as they have saved sufficient money to apply for a holding for themselves, or, as seems to be happening more frequently, they leave agriculture and go into industrial employment. The rate of loss of people from the countryside to the town in Denmark is not as rapid as, for example, in Sweden, because a lack of indigenous raw materials tends to retard industrial development, but there is a steady and continuous drift from the land.

Marketing

Another great advantage enjoyed by the Danish smallholder is the co-operative marketing system which can deal with the dairy produce, pigs, and eggs, he has to sell. This is so well organised in Denmark that it can be said in truth that the smallholder has no marketing problem and the co-operative societies give him all the

economies of large-scale marketing. This leaves the smallholder free to concentrate on production, and there is no practice of weekly visits to one or two markets and no risk of violent fluctuations in the price of the produce he has for sale.

Mechanisation

The Danish smallholder is very conscious of the fact that modern farming is becoming more and more dependent on machinery but finds himself very limited in the extent to which he can mechanise economically. Herein lies one of the reasons for the desire to get more land and to increase the size of the holding to the point where mechanisation is practicable. At one stage it was thought that in a country with such experience of co-operation, this problem might easily be solved by co-operative machinery stations ; but this has not proved to be the solution. The economy of mechanisation means the displacement of horses by tractors, but a smallholder must retain his pair of horses and it was soon realised that a smallholder who hires a tractor to do his ploughing might well spend the day watching the tractor at work, his horses doing nothing in the stable, and have a bill to be paid at the end of the month. Unless the hiring of a tractor enables the smallholder to occupy himself and his horses in some other profitable task, the hire of a tractor increases the cash outlay with no increase in output to compensate for it. As a result, the real value of the machinery stations has proved to be in supplying specialised machinery which is needed only at certain times of the year. A machinery station which can undertake such operations as spraying for weeds, potato lifting, combine harvesting, is of special value to the smallholder.

There have been isolated cases where groups of six or seven smallholders have combined together to purchase a tractor for their joint use, but even here, the development can only be justified if, over all the holdings, some reduction in the number of horses can be achieved. This problem of the mechanisation of the small farm has by no means been solved in Denmark, and if the smallholder is to be able to compete on the world market, he must somehow find a method of getting his costs down to a competitive level. It must, however, be remembered that the basis of their farming is livestock production and in this respect the potential economies by further mechanisation are much smaller than in crop production. The milking machine, barn machinery, electric motors are fairly common on even the smallest farms and though they may not be employed to their full economic capacity they do remove much of the drudgery in the farm buildings.

Purchases

As in the case of marketing, Denmark is also well served by co-operative agencies which enable the smallholder to buy on terms almost as advantageous as a large scale farmer. It may be worth mentioning here that although co-operation plays such an important part in Denmark a fair proportion of buying and selling is done through private firms. The co-operative societies get no special privileges from the government and have to compete with private enterprise, and the competition between the two is sufficiently keen to make sure that the farmer gets the best service.

General Economic Position

From what has been said it is now possible to assess the general economic position of the smallholder in Denmark. He is generously provided with capital, he can buy and sell on equal terms with producers working on a larger scale, he has no weekly wage bill to meet, but the surplus labour in his family must find employment elsewhere within the industry or leave for the towns. His weakness lies in the fact that the area of land on which he has to work tends to be fixed and that this puts an effective limitation on the possibilities of using machinery to its best advantage.

Social Considerations

This is perhaps the most complex aspect of smallholdings in Denmark. It is generally accepted that even if there are doubts about the wisdom of creating more smallholdings, these doubts are forgotten when the social implications are considered. The theory is often advanced that there are advantages in the wide

distribution of property, in men being self-employed instead of working for wages, or in families living independently in the countryside, but behind these theoretical considerations, there remains the question of what standard of living can be achieved by these smallholders.

Many existing smallholders can tell a story of a genuine struggle for survival when they first took over their holdings. They were heavily mortgaged, they had to work unlimited hours and their wives carried no small share of the burden. To-day they find themselves on top of their debts, but still find it necessary in many cases to work an inordinate number of hours every week. Their sons have left, and may not return to take over the holding. The sons who want to get a holding of their own have found it hard of recent years to accumulate any savings and at the present time, the keenest demand for new holdings is coming from the sons of the medium-sized farmers who after some years of farming prosperity are in a position to help their sons to get a holding. Thus, the smallholders are not replacing themselves, but are being replaced and added to by the sons of farmers on a larger scale. This is no doubt partly a question of finance, but it may also be an unconscious revolt against the struggle which they have seen their parents endure in getting themselves established.

The critical factor seems to be the number of hours one may have to work to make a success of a smallholding. Even the paid worker in farming works a fixed number of hours every week and modern industrial labour is strongly organised to set a limit to working hours. Therefore in comparison with the rest of the community, the smallholder is at a disadvantage if he wants to achieve a comparable standard of living. It is on this point that the social argument for smallholding displays its greatest weakness.

The Smallholders' Association

Last June the Smallholders' Association celebrated their fiftieth anniversary at a mass meeting in Jutland, at which some 30,000 people were present. Practically every smallholder is a member of the local association and the local groups are linked to Provincial Federations and they in turn are joined to form the National Association with its headquarters in Copenhagen. It was with some pride that the chairman of the National Association said at their jubilee that the smallholders have become an important factor in the community and their 112,000 members stand on an equal footing with other trade and professional organisations.

This Association watches over the interests of its members in a variety of ways, the two most important being in the provision of technical advisory officers and the safeguarding of their interests in all political matters.

Advisory work to farmers in Denmark is not a State service, but is provided by the farmer's own associations with a contribution from government funds. The two main bodies concerned are the Smallholders' Association and the Agricultural Societies, the latter representing the middle-size farms from 25 to 100 acres. They employ technical advisers for the benefit of their members so that in any one district there are likely to be separate advisers for the smallholders and for the middle-sized farms. While this may show a commendable spirit of independence, it must in many cases lead to a waste of effort, and the quality of the adviser employed will depend to some extent on the financial position of the local society. The advisers are chosen and appointed by the smallholders or farmers themselves and although this may sound excellent in theory, there is a very real danger of perpetuating tradition and conservatism. No bright young man with new ideas would ever be likely to be appointed by a selection committee consisting of the older farmers or smallholders in the district.

Politically, the smallholders are not a united force but most of the leading men are Radicals and members' loyalties are divided between the Social-Democrats, the Radicals and to a lesser extent the Farmers' Party which is a kind of left wing Conservative Party. But as they have to be consulted as a group on all agricultural legislation, their adherence to any one party, or the formation of a party of their own is a matter of minor importance.

One feature of the Danish smallholder

is something of a surprise as the general rule seems to be 'once a smallholder, always a smallholder.' The law against consolidation of holdings prevents any forceful smallholder from collecting a number of holdings and creating a larger unit. But it appears to be rare for a smallholder to move out of this group and to take a larger farm. The reason is probably a reflection of the early struggle which many of them had to get established. After working on a holding for twenty years, having reduced their indebtedness to manageable proportions, built and furnished their home and raised their family, a smallholder and his wife in their fifties are not prepared to start all over again on a larger farm and saddle themselves with another series of loans to be paid off.

One of the most important current problems in Denmark and not only for smallholders, is how to keep alive the interest of the modern generation in the system which they have inherited from their predecessors. The pioneer work in building up co-operation and farming organisations has been done, but no system can survive without fresh initiative, and Danish authorities themselves admit that little or nothing is being done to meet this situation.

RESISTANCE TO CHANGE[1]

by

PROF. C. A. MACE

THERE are many reasons for the growing interest in social and technological change, its causes and effects. The study of causes, however, has been but loosely connected with the study of effects. The literature concerning the effects of technological change is apt to stress the rapidity of change and the difficulties in adaptation to change, while that concerned with causes is more apt to stress the slowness of change and the forces of resistance to change. But clearly the two things are connected, since the rate of change depends on the rate of assimilation of new knowledge and new techniques, and on the rate at which men become adapted to new conditions.

The causes of change in human habits, customs and techniques are extremely complex, as are the causes of resistance to change. It is not helpful to think in terms of such general predispositions as the supposed personality constant of 'natural conservatism' or such general principles as the 'force' of custom or habit. The tempo of change is the resultant of the interplay of mutually interfering forces, with the balance sometimes tipped in one direction and sometimes in the other. It is suspected that a factorial analysis of manifestations of the disposition to change would reveal a complex pattern of general, group and specific factors, with the specific factors often showing the predominant influence. No one is strongly predisposed to change as such—to all and every possible change. Everyone resists some changes. Hence it is not surprising that an organisation concerned with the promotion of desirable changes may itself be highly resistant to suggestions that it should change its own methods of effecting its purpose.

Susceptibility to suggestions of change varies in the course of individual life. Of the seven ages of man, six, it is tempting to say, are ages of conservatism. Conservative tendencies are very strong in young children and in the old; there are just a few critical phases of life in which suggestions for change are readily accepted. Some important changes are imposed, and others welcomed, in the transition from school or college to 'gainful employment.' Of exceptional interest is that point of transition at which the son, more especially the son trained in an agricultural or technological college, succeeds the father in the management of farm or business. For social changes generally, the occasion of marriage and the setting up of an independent home is perhaps more productive of change than any other event in life; and almost as significant is the occasion of the birth of the first child. We need to know not only what changes occur but the manner in which these changes are brought about. There is much to suggest, for example, that some of the changes occur in and through the transition of the generations. They occur not so much through changes in persons as through changes in personnel. The parents of a family of six children are hardly to be expected to change their child-rearing habits on the birth of the seventh child. They are hardly to be expected to change any of their domestic habits on the occasion of their silver wedding. The young man and woman setting up a new home, on the other hand, are predisposed to change from the way of life of their parents. The young mother is prone to say that she is going to bring up her child in a way quite different from that in which she herself was brought up. The son succeeding to responsibility in the family business is going to do things differently from 'the old man.' And the old man himself may at this time agree to changes being made

[1] Paper delivered to Section J (Psychology) at Belfast on Friday, September 5, 1952.

by his son which he was not prepared to introduce himself. Though protesting on principle, his satisfaction with such changes is often ill disguised. Such broad considerations serve at least to indicate some of the critical points of attack towards which educational and advisory services may direct their main attentions ; and frankly to recognise and accept the principles involved may save the impatient reformer many of his feelings of frustration.

Resistance to change varies with place as well as with time. For example, there is a continuous chain of activity from the research laboratory to the farm and field and a passing of scientific knowledge 'down the line.' This useful phrase brings out some common features of two problems of communication. One of these is communication down the line from higher management through the supervisory grades to the man at the bench ; the other is communication down the line from the man in the laboratory who discovers a new substitute for muck, through the agricultural colleges, the farmers big and small, down to the man who actually puts the stuff in the ground. Each *point of transition* in these two lines of communication is a *point of resistance*, each having to be dealt with in a different way. To study and to overcome each of these resistances is the essential function of a specialised educational or advisory service. These services must study their own resistances to change and develop new methods of dealing with the resistances they encounter in the public they serve.

That educational and advisory services directed to promoting change should themselves be resistant to change, though a surprising, is not an isolated, fact. Professor Georges Friedmann, that specialist of our age in the theory of technological change, has made a profound observation on this matter. He notes that the professional and allied occupations, with the possible exception of medicine, are precisely those that are least affected by mechanisation and other forms of technological development. 'No revolution,' he observes, 'has taken place in the work of the small tradesman, the teacher or the lawyer.' As teachers we have, it is true, our projectors, our wire recorders, our film strips and other visual aids ; but in principle these devices take us little further than the Victorian 'magic lantern.' It is true, also, that in the construction of charts, diagrams and posters we can call on the best and latest resources of modern publicity methods. But the actual in comparison with the possible is still more than a little old-fashioned. There has been no technological revolution in education or in the advisory services.

But what would constitute such a revolution ? What should we accept as a fundamental change ? One answer is this :—

Education and the advisory services have relied in the main upon mass methods of communication. They have broadcast the seed, trusting that some of it would sprout. Information is distributed without regard to what is already known and what needs to be known. No adequate checks are made upon the effects produced, and hence there is no factual basis on which mistakes can be corrected. Action persists indefinitely without sufficient evidence that the action taken produces the effects intended. It could be accounted a technological revolution if educational and advisory services changed their methods in each of these three respects—if information, instead of being diffused was focused on those most disposed and able to turn this information to good effect ; if the information was related, in content and form, to actual and established needs ; if by means of a suitable 'feed back' the effects produced were accurately assessed. Signs of such a technological revolution—the use of precision methods in education and the advisory services—may be discerned in various unexpected places. Experiments worth watching are in progress in several holes and corners, all peripheral to our general educational system.

The largest of these holes and corners is the B.B.C., where very important studies are in progress under the name of 'Audience Research.' The general aim of these investigations is to increase the precision with which a selected message can be delivered to a particular target audience, and to increase the precision with which the impact of the message can be assessed. There is an element of paradox in the situation. At a time when

the word ' broadcasting ' has come to be a synonym for ' mass communication ' and ' diffusion,' ' Broadcasting '—the thing—is becoming more and more a technique for focusing a beam of specific intelligence upon a quite particular public under particular conditions with particular ends in view. It is the use of such techniques, not the use of machines and gadgets, which constitutes a technological revolution.

Audience research is no doubt important in itself and important for the B.B.C. For the psychologist the interest lies in the generality of the principles involved. The principles apply to every form of educational or advisory communication. They apply to the poster as simple as ' Mind how you go,' they apply to the advisory leaflet on the Colorado Beetle, they apply to the course of lectures on Cost Accountancy, they apply to the whole curriculum of studies prescribed for a B.Sc. degree. In each of these cases there is a message directed to a target audience. In each we could, and we should, define with precision the message to be delivered, the characteristics, the attitudes, the background, the level of comprehension and the coefficients of resistance of this target audience. In each we could, and we should, check upon the impact of the communication. What is being done to assess the impact of a B.B.C. programme could in principle be done to assess the impact of any poster, or of a course of lectures for the B.Sc. degree. Clearly there are distinct methodological advantages in beginning with specific cases with limited objectives. It is right that research of this kind should begin in fields peripheral to the general educational system. It is not, however, essential for it to be restricted to the problems of the B.B.C. Nor is it in fact so restricted. Training for foremanship might not seem a promising subject for precision training methods. Nevertheless examples from this field can be cited. In a recent number of *The Vocational Aspect* Mr. Alfred Flook has described a promising experiment conducted by some instructors in building schools. The problem was to provide a revision course for general foremen covering the main divisions of building theory and practice. The course was to be comprehensive in scope but severely restricted in duration, and no one could say in advance what could be taken as already known by this target audience. The problem was solved by constructing a series of standard tests or examinations each to be taken *not at the end but at the beginning of the relevant sections of the course provided.* The teachers then designed their lectures on the basis of what were thereby shown to be the significant gaps in the foremen's technical knowledge.

Judged by the standards of ' fundamental research ' the whole procedure was perhaps a little rough and ready, but in comparison with traditional ' hit or miss ' educational practices it was almost a model of precision. The device, in any case, readily lends itself to development and refinement.

A more elaborate and more ambitious study in a closely related field is that of Mr. Peter Castle of the National Institute of Industrial Psychology, who has set himself to apply precision methods in ' human relations ' training. Notwithstanding the immense expansion in this field of instruction in recent years the whole subject is a tissue of unknowns. We do not know, in any scientific way, what to teach, we do not know how to teach it, we do not know whether our teaching is having any effect.

On the basis of certain plausible and widely accepted assumptions as to what should be taught and how we may teach it, Mr. Castle proceeds by a skilful adaptation of attitude scales and other methods of assessment to determine the impact of the instruction upon the selected target audience. Here again what is significant in the study lies not so much in the conclusions reached concerning the impact of this sort of instruction on the given sample of foremen as in the demonstration of a technique by which the impact of any kind of training may be determined with some precision. It is not simply a matter of a once-for-all validation of a method of instruction. It is also a matter of providing a routine check upon the degree to which the message received is the message dispatched.

What, it may be asked, has all this to do with the resistance to change encountered by an advisory service? The bridge lies in the fact that in large measure the resistance to change lies in the resistance to

communication—the refusal, the disinclination, the incapacity or the simple failure to receive a message. Not all failures to receive a message arise from the resistance to change. Some failures are simply failures of the message to arrive. We are perhaps too ready to assume that all the trouble is located at the end of reception. Some of the sources of failure in communication are located in the transmitter and in the process of transmission. Despite plausible evidence to the contrary, men are not always implacably opposed to the acceptance of information to their own advantage, information, that is to say, which could contribute to the satisfaction of their wants and their needs.

The functions of an advisory service are to deliver a message, to produce conviction that the message is to the advantage of its recipient, and to provoke appropriate action—always to provoke action. It can perform these functions more effectively if it delivers the message to the right person, frames it in a form appropriate to that person, delivers it at the right time and presents it in the right way. There is considerable scope for immediate improvements in most of our advisory services in each of these respects. There is scope for greater concentration, sharper focusing, and for a more discriminating selection of the target public to which advice may be directed. There is scope for greater technical efficiency in the design and presentation of the informatory material. What the B.B.C. has done, for example, and is still doing, in assessing the comprehensibility of its programmes could be done by any advisory service. Many advisory leaflets when they reach their public still smell strongly of the laboratory of the Ministry in which they were prepared. Communication of this kind would gain from a critical evaluation, at the drafting stage, by a panel of representatives of the public for whom they are intended. More might be done in the way of accurate timing in the dispensation of advice. It makes sense to say ' Do it now ' only if it can be done at that time. Perhaps we need to know more about the times at which men actually make their decisions so that advice is not given either too soon or too late.

' Follow up ' is of crucial importance. It is always rewarding to inquire, after advice has been given, whether it has been accepted ; if not, why not ? and if it has, with what result ? A follow up policy not only affords the necessary ' feed back ' to the advisory service, it also provides a useful reinforcement to the advice itself. Advice is not always taken immediately it is given. There is often a time lag, and it often needs to be repeated. New ideas may be accepted only after the novelty has worn off. To implement this policy might seem an exacting demand to place upon any advisory service, but again the case can be pressed that concentration of effort is better than diffusion.

On every hand it is agreed that the most important condition of the acceptance of advice is the ' way in which the advice is given.' This of course is a realm of intangibles, and one in which the sentiments expressed tend to be as pious as they are platitudinous. But it is a realm into which some precision is beginning to be introduced. Natural understanding, tact and common sense can be reinforced by scientific knowledge.

There are common mistakes which could be avoided. To take but one example, it is often said that if ' you want to sell a man an idea you must so present it that he believes the idea to be his own.' This is one of those clever-cynical remarks which profoundly misrepresent a profoundly important truth. The fact could better be stated ' If you want to sell a man an idea you must so present it that he *rightly* believes the idea to be his own.' It must in fact be in part his own idea, or it must become so. This is one aspect of the concept of ' participation,' the importance of which has come to be recognised largely in consequence of the studies of Lewin. Advice can rarely be given in the form ' Do exactly as I say.' It must always be in some degree in general terms, and the intelligent co-operation of the recipient is always needed to adapt it to the particular situation in which it can be followed.

This is one among many other reasons why the technical colleges and similar institutions are likely to be among the most important media for the infusion of scientific knowledge into industry and commerce. The students in these colleges are likely to possess the lowest coefficient of resistance to change, and the greatest

readiness to co-operate in the application and adaptation of new knowledge ; and the teachers in these colleges are in one of the key positions on the lines of communication from the laboratory to the factory or farm.

There are many things that affect resistance to change over which we have little or no control. There is much that we do not know about some of the things which we might perhaps control, but we can, at least, say what the problem is : It is to get the right message, in the right form to the right public, in the right way at the right time—and to check up on results as we go along. All this could be done better than at present if the advisory services were themselves serviced by advisory research concerned with their problems of communication. This is clearly a matter for co-operative research. It would call for co-operation between the scientists providing the content of the advice and the scientists concerned with the problems of human motivation and human communication. The problems with which the B.B.C. audience research is concerned could be stated and tackled in more general terms, and the results obtained would have a wider field of application.

Not less important is the co-operation of those for whom the advisory service is provided, and this may require a new approach in scientific research. Among ourselves, as scientists, we talk about ' scientific method ' and scientific research, but we need to be careful how and when we use language of this kind. To talk to the farmer or the practical industrialist about ' scientific method ' may give the impression that we are trying to sell him something he cannot use. To talk of ' research ' may conjure up visions of a programme stretching out to Kingdom Come. The message is simpler than that. What the scientist calls ' scientific method ' is in essentials what the practical man describes as ' being business-like '—getting clear as to what you want to do, and doing it in an orderly way. ' Research ' after all is only conducting well planned observations and experiments with a view to getting relevant facts. For an advisory service, ' science ' itself is something which has to be passed down the line, and at every point in the relay the idea needs to be put in a slightly different way. The problem of resistance to change is in part the problem of points of resistance in the process of communication.

HUMAN BIOCHEMICAL GENETICS

SECTION I (Physiology), Section D (Zoology), and Section J (Psychology) devoted the afternoon of September 9, 1952, to a joint session on Human Biochemical Genetics. The subject was introduced by Prof. L. S. Penrose, of University College, London. He was followed by Dr. H. Harris, University College, with a paper on recent developments which made special reference to *Cystinuria*. Dr. Valerie Cowie, of Maudsley Hospital, then dealt with *Phenylketonuria*, which describes a condition in which an error of metabolism is accompanied by mental defect. Dr. S. P. Datta, University College, discussed the comparative biochemistry of *Aminoaciduria*. Finally Prof. D. C. Harrison, of Queen's College, Belfast, gave a survey of studies in Northern Ireland on *Familial Methaemoglobinaemia*.

The papers, which have been edited by Prof. L. S. Penrose, appear below in the order in which they were given.

INTRODUCTION

by

Prof. L. S. Penrose

THE foundations of the exact study of human genetics were laid down by Garrod in his work on alkaptonuria and by Landsteiner in his work on the A B O blood groups. These investigations, carried out between 1900 and 1902, described human characters which followed simple rules of inheritance. The precision of the tests by which these characters were recognised enabled their familial patterns to be accurately described.

In the case of the blood group antigens, the critical test was clumping of red cells when exposed to certain sera. This test (or its equivalents) forms the basis of one main branch of the subject. The chemical analysis of this type of reaction is far too subtle to be carried out by ordinary methods but precision and specificity are as great as if the chemical basis of the reaction were known. Landsteiner, himself, realised that immunological reactions demonstrating inborn differences between people were, like immunological reactions of bacteria, ultimately explicable in biochemical terms. Recently, knowledge in this field has been greatly advanced by the work of Morgan and his colleagues, who have established many facts about the chemical composition of the blood group substances although details, such as the exact reason for the different serological reactions of the A and B substances, still remain unexplained. The enormous extension of researches on blood antigens in recent years and their success in the hands of such workers as Race and Weiner shows the prodigious possibilities in this field for detecting inherited human biochemical specificities.

The other main branch of biochemical studies in human genetics, is that initiated by Garrod. This branch deals with the differentiating of individuals by ordinary chemical tests or their equivalents like colour reactions. This is the topic with which the present symposium is concerned.

At first the idea of inborn chemical specificities differentiating one person from another was slow to develop, although it contains an important clue to the use of genetics in medicine. The study of morphological characters in man formed for many years, e.g. between 1910 and 1940, the central object of genetical studies. Progress was very slow because most morphological inborn traits do not follow simple genetical rules. The precise detection of the effects of single genes in such a trait as stature, head shape or eye colour is still a very far-off goal. The situation is even worse when physiological or psychological variations are examined for hereditary influence. During that epoch, Haldane was one of very few investigators who realised the importance of biochemistry as likely to form a focal point in this subject. Moreover, in 1934 when Fölling discovered phenylketonuria he too was met with incredulity. Here was, it seemed, a new and startling phenomenon, a biochemical anomaly which, unlike the harmless alkaptonuria described by Garrod, could disturb the mental processes. Actually this was not really such

a new idea because, many years earlier, several degenerative hereditary nervous diseases obviously due to biochemical peculiarities had been accurately described.

The stimulus of work done on the chemistry of floral pigments and upon the genetics of bacteria and moulds has also been felt in the human sphere. The conviction has now deepened that, whether we are dealing with plants or with animals, the immediate effect of gene action is to influence chemical changes. The chemical change is usually assumed to be the production of a specific enzyme or catalyst. In most cases the special gene concerned (which we assume to have arisen by mutation) has the effect of failing to produce a catalyst necessary for the metabolism of some important substance. In recessive conditions like alkaptonuria, phenylketonuria and the amaurotic idiocies, this lack of a catalyst or enzyme is the rule. The carriers have one normal allelic gene which is adequate to produce the enzyme. Sometimes, however, one normal gene is insufficient to compensate for its abnormal mate : too little enzyme is produced to do the necessary work and the carriers, i.e. heterozygotes, themselves show signs, usually slight, of the abnormal trait. Such a gene is imperfectly recessive : this phenomenon occurs in sickle cell anaemia and some types of cystinuria.

It is convenient to classify the known types of hereditary biochemical anomalies by the substances involved in the test reactions as shown in Table I.

A primary aim of human genetical enquiry is to reduce all characters as far as possible to chemical differences : this makes accurate scientific investigation possible, especially if the trait measured is found to be closely associated with the familial appearances of a single genic mechanism. We can then examine how the anomalous trait affects the constitution of the individual for good or ill. With the harmful traits, knowledge of the causal mechanisms can help in planning their alleviation or cure. In this way, too, the study of human constitution becomes an exact science, and is freed from ambiguities and superstitions which surround the cult of physical types.

In phenylketonuria, abnormal substances are found in the sweat. Perhaps soon we shall find out that sweats are as different and as characteristic as bloods and salivas. If so, it will not be so difficult as formerly to understand how specific the smells of different people are to dogs and especially bloodhounds. As Garrod, himself, fully appreciated, besides separating individuals within one species, similar biochemical differences also separate one species in the animal kingdom from another. We shall hear about these in the course of the symposium from Dr. Datta whose work also emphasises the importance of distinguishing nutritional from inborn defects.

Some decades ago, inborn chemical differences between people were regarded as unimportant curiosities. Now they have been shown to be of quite general significance in the causation of natural variations within the human species. They take a central place in human genetical investigations.

TABLE I

Some inborn anomalies characterised biochemically

1. Protein metabolism.
   - (*a*) Aminoacidurias ; Alkaptonuria, phenylketonuria, tyrosinosis, cystinuria, β-amino *iso* butyricaciduria and albinism.
   - (*b*) Protein abnormalities connected with haemoglobins ; sickle cell trait, thalassaemia, methaemoglobinaemia.
2. Lipoid metabolism.
   Amaurotic idiocy (cerebromacular degeneration), xanthomatosis, hypercholesteraemia, gargoylism.
3. Carbohydrate metabolism.
   Pentosuria, fructosuria, renal glycosuria and, very indirectly, diabetes mellitus.
4. Miscellaneous.
   Gout, porphyria, taste deficiency, red hair, etc.

RECENT DEVELOPMENTS, WITH SPECIAL REFERENCE TO CYSTINURIA

by

Dr. H. Harris

ALTHOUGH the general basis of the subject was first laid down some fifty years ago by Garrod, our ideas and knowledge are still at a very rudimentary level. Broadly speaking we may say that human biochemical genetics is concerned with three things. In the first place, it characterises human variations in biochemical terms as precisely as possible with available techniques, secondly, it analyses their genetical backgrounds and, thirdly, it attempts to give as full an account as possible of the processes by which individual genes produce their particular effects.

Recent developments include the discovery by Pauling and his colleagues that haemoglobin synthesis is genetically controlled and that different individuals may possess different kinds of haemoglobin with quite distinct properties. Another example is the isolation by Dent and his colleagues of a new aminoacid, β-amino*iso*butyric acid, in normal human urine. There are great differences in the urinary output of this substance from one person to another, and these variations are genetically determined.

Another kind of development has occurred following the application of the newer biochemical techniques to the study of some of the classical hereditary metabolic disorders, such as porphyria and cystinuria. These studies have revealed many unsuspected complexities in the subject.

The condition known as cystinuria provides a very good illustration of this point. It was first recognised by the discovery of a renal stone of unusual composition by Wollaston in 1810. Similar cases were identified periodically over the next hundred years and it was found that the stones were almost entirely composed of the aminoacid cystine. The condition appeared to be hereditary because, although it was evidently uncommon in the general population, more than one member of the same family was not infrequently found to form renal stones of the same type. Such individuals excreted cystine continuously in large quantities and cystine crystals were very often to be found in the urinary sediment. It then emerged that some individuals who appeared to be in perfect health and had no history of signs of stone formation nevertheless excreted large amounts of cystine daily.

Recently the occurrence of cystinuria in patients with certain rare forms of rickets attracted attention. As originally described these patients were invariably infants and the whole syndrome comprised failure to thrive, bouts of vomiting, rickets resistant to the usual anti-rachitic doses of vitamin D, chronic acidosis, polyuria, glycosuria of the renal type and hypophosphataemia. This symptom complex is sometimes referred to as cystine rickets, other names are Lignac's disease and the syndrome of Fanconi, of de Toni or of Debré. The prognosis is in general rather poor and few cases have survived for many years. Post mortem examination has often revealed crystals of cystine extensively deposited throughout the body and this phenomenon, known as cystinosis may on occasion be recognised during life by the examination of the bone marrow and of deposits in the cornea of the eye.

It was generally assumed until very recently that all such varieties of clinical abnormality represented different degrees of severity of a single hereditary metabolic disorder, whose most characteristic sign was the excretion in large quantities of cystine in the urine. The genetics of the condition however have always remained obscure.

The application of the technique of partition chromatography on filter paper to the study of the urinary aminoacids in these cases has led to a complete reorientation of outlook. It has become clear that cystine is not the only urinary aminoacid excreted in large and abnormal amounts. In a series of cases of the classical type of cystinuria with renal stone formation, not only cystine but also the basic aminoacids lysine and arginine were present in grossly increased quantities while all other urinary aminoacids appeared to occur in normal amounts. In cases of patients showing the typical features of Lignac's disease or the Fanconi syndrome, an entirely different pattern of urinary aminoacid excretion occurred. Here there was a generalised aminoaciduria in which abnormal amounts of serine, glycine, alanine, glutamine, proline, lysine, histidine, arginine, threonine, valine, the leucines, phenylalanine, tyrosine and cystine might be found. The cystinuria, previously identified in such cases, seemed to be merely one facet of a much more generalised disturbance of urinary aminoacid excretion.

In spite of minor individual variations, the two classes of case give quite distinctly different chromatographic results, presumably implying distinct differences in the underlying biochemical peculiarities leading to the aminoaciduria. This view was confirmed by the results of family studies. Among the relatives of the patients with the cystine-lysine-arginine pattern of aminoaciduria examples of this same type are encountered. Similarly, the generalised type of aminoaciduria runs true to type in individual families.

A third apparently quite distinct group of cases has also been identified, in which there is a generalised aminoaciduria sometimes involving and sometimes not involving cystine. But here the clinical features are those of the disorder first recognised by Wilson in 1912 and known as hepato-lenticular degeneration. This is a hereditary disease in which pathological

changes are found characteristically in the mid-brain and in the liver. It bears no relation to the Fanconi syndrome and presumably represents a distinct type of aminoaciduria which, according to whether cystine is more or less prominent among the aminoacids excreted, may or may not come under the classification of 'cystinuria.' Thus both from the results of biochemical and familial investigations there is every reason to believe that 'cystinuria' as originally considered is not a homogeneous entity and cannot be regarded from the genetical standpoint as a 'unit character.'

A preliminary chromatographic examination of the pedigrees obtained in the cystine-lysine-arginine group made it quite clear that the situation was even more complex than had originally been anticipated. It has, however, been possible to take the matter further by quantitative studies of cystine excretion using the technique of polarography, a procedure which enables a rapid and reliable estimate to be made of the amount of cystine present in the urine. On the average, normal people excrete about 60 mgm. a day, and cystinurics with stone formation average about 750 mgm., though there is quite a lot of variation. We have been able to study a series of some 20 families, in each case starting off from a patient with cystine stones and a typical cystine-lysine-arginine pattern of aminoacid excretion, and have performed urinary cystine estimations on as many relatives as possible in each case. A somewhat surprising picture has emerged. In some families, cystinuria appears to segregate quite sharply as a typical rare mendelian recessive character. In these families we find only brothers and sisters affected, and there is an increased incidence of parental consanguinity. The affected individuals may or may not have formed renal calculi but they all excrete between 400 and 1,200 mgm. of cystine a day, that is, 10 to 20 times the amounts of cystine excreted by the normals. Their parents, children and other relatives all have cystine values within the normal range. Thus, in these families, it seems a reasonable hypothesis that the affected individuals are homozygous for a certain gene and that the heterozygous are indistinguishable from normals.

In the other group of families the familial picture is quite different. Here are found all degrees of cystine excretion among the relatives varying between normal values and the high values of the cystinurics with stone formation. In several families, both the parents, and all the children of the propositi fall into an intermediate class, and also a varying number of uncles, aunts and other relatives. This kind of familial distribution can be understood on the hypothesis that, in these families, 3 genetically distinct types of individual occur: the normal, those heterozygous for the abnormal gene, and those homozygous for the abnormal gene. The heterozygotes show an excretion of cystine averaging about 150 mgm. a day, that is to say, about 2½ times to 3 times that occurring in the normals. On the whole, they do not tend to form cystine stones because the concentration of cystine in their urines is probably never high enough. The homozygotes have a cystine excretion averaging about 750 mgm. a day and here there is a very real risk of stone formation and its attendant disturbances.

Though the homozygous condition is very rare, heterozygotes are relatively common and, in a survey of some 1,000 university students, we found that 4 quite definitely came into this class. As risk of their developing renal stones is very small, they cannot be regarded as suffering from any particular disadvantage as a result of their curious anomaly. They must be considered as biochemical variants within the normal population. If they marry persons of similar genetical constitution, 1 in 4 of their children will be liable to develop cystine calculi. This illustrates very clearly the interconnections between normal and pathological variation within a population.

The question arises as to whether the genes causing the high cystine excretion in the two groups of families are allelomorphic or at different chromosomal loci but it has not yet been possible to decide between these two alternatives.

Garrod put forward a simple hypothesis to account for all the diverse biochemical manifestations which may be observed in these inherited metabolic variations. He suggested that in each condition the body was unable to perform some particular step in the normal course of metabolism. This was due to the congenital absence of an enzyme. The abnormal concentrations of particular metabolites in the body fluids and the clinical signs and symptoms, with which they were associated could all, he believed, be ultimately traced back to the inability to carry out this single step in the metabolic chain. While this theory

has an obvious application to such conditions as phenylketonuria and alkaptonuria its application to cystinuria has always been difficult.

The occurrence of an inherited disorder, characterised by the excretion of abnormally large quantities of some particular metabolite, can also be interpreted in other ways. In particular it may arise as a result of some specific peculiarity in kidney function. That this is the explanation of the condition called renal glycosuria has been known for many years, and recently Dent has put forward the view that cystinuria of the cystine-lysine-arginine type has the same kind of explanation. He suggested that in these individuals the reabsorption of the aminoacids cystine, lysine and arginine, by the renal tubules from the glomerular filtrate was deficient and that consequently the substances appeared in large quantities in the urine. The main direct evidence for this hypothesis rests on the comparison of the concentration of these aminoacids in the blood plasma of cystinurics and of normal individuals. On the view that cystinuria arises from some kind of block in the intermediary metabolism of these substances one might expect that in this condition they would accumulate in the body fluids and that consequently their level in the blood plasma would be considerably higher than in normal people. Thus in phenylketonuria, a block in the intermediary metabolism of the aminoacid phenylalanine leads to a twentyfold increase in the concentration of this aminoacid in the blood and cerebrospinal fluid. On the view that cystinuria is a renal peculiarity, no such rise in plasma levels of cystine, lysine or arginine would be anticipated, if anything they might be slightly lowered. This has, in fact, been found to be the case recently by Fowler, Harris and Warren. One might even go one step further and envisage the peculiarity in cystinurics as arising from a failure in one or other of the steps involved in reabsorption, due to the absence or relative inefficiency of the particular enzyme concerned in catalysing this step.

A satisfactory explanation of why only some cystinurics form stones has not yet been forthcoming. Cystine has a much lower solubility than the other aminoacids. Consequently it tends to crystallise out when excreted in large amounts and so the raw material for stone formation is available. It is probable that unless a level of about 0·4 gm. a day is reached the chances of stone formation are quite remote. On the other hand, many individuals with apparently similar daily outputs differ according to whether or not they form stones. A more exact knowledge of the factors involved might well lead to the development of therapy completely preventing stone formation in susceptible individuals. In the meanwhile it seems important that the close relatives of all patients with cystine stone formation should have their urine examined quantitatively for cystine. This would enable all predisposed individuals to be identified and kept under observation. Attention to their fluid intake and the early treatment of urinary tract infections no doubt would provide a useful prophylactic approach.

Phenylketonuria

by

Dr. Valerie Cowie

In 1934 a Norwegian biochemist named Fölling, made an observation which led to the discovery of a hitherto unrecognised disease. In testing the urine of a mentally deficient patient for acetone bodies with a solution of ferric chloride, he found to his surprise that a deep green coloration was produced. This stimulated him to make a survey, testing the urines of many mental defectives and their relatives with ferric chloride. It soon became apparent that the urine, which produced a green coloration with this solution, was excreted only by certain mental defectives and never by people of normal intelligence. Moreover, the defectives excreting this kind of urine conformed to one type; they were markedly fair-haired, fair-skinned and blue-eyed, and were usually of very low grade intelligence, frequently being idiots. The substance excreted in the urine was found to be phenylpyruvic acid, and Fölling named the condition phenylpyruvic oligophrenia. Several alternative names have been suggested, but the term phenylketonuria is conveniently in agreement with those used for other biochemical anomalies like cystinuria or fructosuria.

Since the time of Fölling's discovery, many new observations have been made as to the clinical picture presented by phenylketonuric patients. Their skin is soft, smooth and fine in texture and it may show pigmented patches. They are often subject to eczema and dermatitis. Dwarfing of stature and slight microcephaly occurs. The stance is peculiar in the

majority of cases, the patient standing with hips or knees slightly flexed. Kyphosis is sometimes present. The incisor teeth are characteristically widely spaced and the upper jaw is prominent.

Neurological signs have sometimes been observed. The reflexes are always very brisk. Epileptic fits are described as occurring in the early years of severely mentally affected patients. Phenylketonurics tend to be hyperkinetic and to show stereotyped digital mannerisms, often pill-rolling or flicking in character, being rapidly and delicately performed.

The metabolic error in phenylketonuria is an impairment in the metabolism of phenylalanine. This substance is present at abnormally high levels in the body fluids ; the tissues of the patient become saturated with it. It is believed that the normal route of phenylalanine metabolism is through tyrosine but the conversion of phenylalanine to tyrosine is blocked in phenylketonuria, and the only pathway for the breakdown of phenylalanine leads by oxidative deaminisation to phenylpyruvic acid.

The output of phenylpyruvic acid is remarkably constant for the individual in phenylketonuric cases. I carried out quantitative estimations on my series of fifteen patients and found that from day to day, while the diet remained the same, the urinary output of phenylpyruvic acid rarely deviated from its average level by more than 0·1 or 0·2 of a gm. The usual daily excretion has been put by other workers as approximately 1 gm. daily. My figures are in accordance with this. The lowest average daily output in my series was by the most intelligent of the group, a dull and backward patient who excreted an average of half a gm. daily. The highest average daily output was 2·9 gm. by a patient of idiot grade. The number of patients in my series was too small for a conclusion to be drawn between connecting the amount of phenylpyruvic acid excreted and the mental level of the patient.

The coincidence of cases in sibships has been so frequently observed in phenylketonuria that a genetical causal mechanism is highly probable. Penrose in 1935 advanced the hypothesis that the gene for phenylketonuria was not completely recessive, but that it exerted an influence on the heterozygotes, predisposing them to mental breakdown. However, Jervis later concluded that the disease was determined by an autosomal fully recessive gene.

Search for linkages between the genes for the blood groups and for phenylketonuria have been made by Penrose and Munro, and in my own series, but further material is required before conclusions may be drawn safely, though linkage with the A B O system is suspected.

It is attractive to postulate that the metabolic dysfunction in this disease is due to the lack of a specific enzyme necessary for the transformation of phenylalanine to tyrosine—and that the lack of this enzyme is caused by a single gene. Delay, Puchot and Bertagna, in the belief that the evidence of enzyme-lack in phenylketonuria was almost conclusive, carried out experiments to find whether in phenylketonuria there was a congenital absence of a phenylalanine-oxidase in the circulating blood, but the result of this work was completely negative.

There are certain indications that the liver may be the seat of the metabolic error in phenylketonuria. These indications include (*a*) the finding of tyrosine in the perfusion fluid after perfusing normal mammalian liver with phenylalanine, (*b*) pathological changes in phenylketonuric liver, and (*c*) changes in the chromatograms of phenylketonuric urine, suggestive of liver damage. Delay and his co-workers carried out a galactose tolerance test on a phenylketonuric patient and their findings were similar to those obtained in acute hepatitis. Galactose tolerance tests were also carried out in eight patients of my own series. In three cases strongly positive results indicative of liver dysfunction were obtained. A fourth gave a weakly positive result. Liver biopsies, however, on two of the cases with positive results failed to reveal any gross abnormality.

Experimental feeding of various substances has been carried out by many workers in phenylketonuria, chiefly for one of two reasons : either to clarify the picture of the metabolic disorder, or for the trial of possible therapeutic methods. Tyrosine was added to diets by Jervis and by Penrose and Quastel. Jervis found that the phenylpyruvic acid output was not increased when 10 grammes of tyrosine were fed to a phenylketonuric patient. The findings of Penrose and Quastel were in agreement with this. They also found it was impossible to induce phenylketonuria in any control patients by feeding tyrosine.

Three patients in my series were fed with 20 gm. laevotyrosine daily for four months.

This led to the excretion of parahydroxphenylpyruvic acid in the urine, a phenomenon which also occurred in control experiments with non-phenylketonuric subjects. It indicates that the metabolism of tyrosine can proceed unimpaired. As regards any therapeutic effect by the feeding of tyrosine, it was observed that two of the three patients appeared to become more active and to show more interest in their surroundings, but psychological testing showed no change in intelligence or developmental level.

The feeding of glutamic acid to a phenylketonuric patient by Delay, Puchot and Bertagna was claimed to bring about an improvement in the condition, including a measurable rise in the level of intelligence. Later, Woolf and Vulliamy treated two phenylketonurics with glutamic acid, but no significant increase in intelligence followed.

The relationship of the biochemical error to mental defect in phenylketonuria is a question which still remains unanswered. In the search for possible abnormalities seated in the brains of phenylketonuric patients, electroencephalographic studies have been made from time to time, but the reports have shown such diversity, that no conclusion pointing in any one direction can be drawn.

It seems most likely that the impairment of cerebral function is ultimately due to the abnormally high concentration of phenylalanine or its breakdown products circulating in the blood. The answer to the problem of treating the condition may lie in the discovery of some means of reducing the concentration of these substances. It is likely that long exposure of the brain to the injurious concentrations of phenylalanine and its catabolites may render it unresponsive to any reduction of these concentrations. If this is so, the best subject for experiments directed towards finding a successful treatment for the condition, is the new-born phenylketonuric child. This consideration in itself is good reason for attempting the early diagnosis of phenylketonuria by the simple ferric chloride test.

The Comparative Biochemistry of Aminoaciduria

by

Dr. S. P. Datta

The results of a survey of the urinary amino-acid patterns in a number of animal species are shown in Table II. They were obtained in collaboration with Dr. H. Harris by running 10–50 microlitres of urine, desalted when necessary, on two-dimensional (20 × 20 cm.) paper chromatograms, phenol and collidine being the solvents used.

It will be seen from the table that glycine is almost always present, while alanine and glutamic acid (or glutamine) occur very frequently.

The column headed ' cat spot ' indicates the presence of a hitherto unknown and as yet not fully identified sulphur containing aminoacid. This substance has been purified from cats' urine by Westall. We found it in specimens from 32 cats kept either at University College or in the Biochemistry Department of the University of Cambridge, and we are indebted to Prof. F. G. Young for an opportunity of examining these animals. The cats were of a wide variety of colours. None of them excreted more than a trace of taurine. The diet of all these cats was made of raw beef, cooked liver, codliver oil, Marmite and bone meal. Two kittens fed on fish for three months from weaning, both showed taurine in their urine and at the most only a trace of ' cat spot.'

From the table it will further be seen that only three other animals, all felidae, showed 'cat spot ' in their urines, and further that no case was encountered where both ' cat spot ' and taurine occurred in the same urine. Further, apart from the case of the Kenya genet, one may generalise in saying that the only sulphur containing aminoacid in the urine of these animals was either taurine *or* 'cat spot.'

The occurrence of cystine in the urine of the Kenya blotched genet has been confirmed for a number of these animals at the London Zoo and for several specimens which have been kept in the laboratory. The amount of cystine in the urine has been estimated polarographically and has been found to be of the order of 1–2 mg./ml. At no time have crystals of cystine been seen and the question arises as to how so much cystine can be kept in solution in these urines. Possibly a study of these animals might have some relevance to cystinuria in man. We have not had the opportunity of examining other varieties of genets and are thus unable to say how limited the phenomenon is. We have, however, found cystine in the urine in a number of examples of the Kenya genet, which were brought from that country at different times and some of which were of the melanistic variety.

TABLE II

Substances detected by paper chromatography in animal urines

Species	Glycine	Alanine	Glutamic acid or glutamine	Taurine	'Cat spot'	Cystine	Methyl histidine
Cat	+	+	−	−	++++	−	++++
Lion	+	+	+	+	−	−	+++
Tiger	+	+	−	+	−	−	+++
Leopard	+	+	−	−	++	−	++
Puma	+	+	+	++	−	−	++
Indian leopard cat	−	−	+	−	++	−	++
Serval	+	−	−	−	−	−	++
Ocelot	+	+	+	−	++	−	+++
Fishing cat	+	−	−	−	−	−	−
Genet (Kenya)	+	+	−	+	−	++++	+
Binturong	−	−	−	+++	−	−	−
Pole cat	+	+	+	+	−	−	−
Dog	+	+	+	+++	−	−	+++
Rat	+	+	−	++	−	−	−
Mouse	−	−	−	++++	−	−	−
Rabbit	+	+	+	−	−	−	−
Guinea pig	+	+	+	−	−	−	−
Golden hamster	+	+	+	+	−	−	−
Rhesus monkey	−	+	+	+	−	−	−
Horse	+	+	+	+	−	−	−
Cow	+	−	−	−	−	−	−
Goat	+	−	−	−	−	−	−

Methyl histidine gives a green colour with ninhydrin and has been described as occurring variably in the urine of man. We observed that it was always present in the urine of cats kept on a diet consisting mostly of meat. Also it was absent from the urine of animals such as rats, mice, rabbits and guineapigs which were on diets consisting mostly of vegetable origin. We thought it likely that the methyl histidine in the urine was derived from anserine, a dipeptide of methyl histidine and β-alanine, which is known as a constituent of muscle and therefore present in meat diets. Our experiments on human subjects showed that day-to-day variations in the meat intake can account for the variable occurrence of methyl histidine in specimens of urine.

The presence of an enzyme in various tissues which is able to hydrolyse both anserine and carnosine has been reported, and it is interesting that the mucous membrane of the small intestine of carnivores shows a greater carnosinase activity than that in non-carnivores. Thus we feel that the ingested anserine is hydrolysed in the body, the useful β-alanine is further metabolised, while the methyl histidine is excreted in the urine. The results of these enquiries demonstrate that, while there are certainly inborn differences in the metabolic processes of different animal species, some observed peculiarities can be shown to be mainly determined by diet.

METHAEMOGLOBINAEMIA

by

Prof. D. C. Harrison

THE work reported upon in the present communication was done in collaboration with Prof. H. Barcroft, Dr. Q. H. Gibson and others. There were nine people suffering from methaemoglobinaemia in three families living in the north of Ireland. The investigation arose out of an observation by Deeny that the blue-grey cyanosis occurring in patients with this disease can be removed by large doses of ascorbic acid. In methaemoglobinaemia, an abnormally large proportion of the blood pigment haemoglobin (Hb) is changed to the corresponding ferric compound methaemoglobin (Met-Hb) which is useless for oxygen transport. In normal blood, the equilibrium Hb $\rightleftarrows$ Met-Hb lies far to the left owing to the action of enzyme

oxidation-reduction systems in the red blood corpuscles. These systems reduce the Met-Hb, which is constantly being formed from Hb, and prevent the Met-Hb from accumulating in more than traces. In the type of methaemoglobinaemia caused by certain drugs or (in infants) by nitrates in drinking water, the oxidation of Hb to Met-Hb becomes so fast that the restoring enzyme systems are temporarily unable to maintain the normal level of Hb, but conditions return to normal when the offending agent is removed. In familial methaemoglobinaemia, on the other hand, the rate of production of methaemoglobin is normal but its rate of reduction is abnormally slow, so that it may accumulate to form as much as 40 per cent. or more of the total blood pigment. Large doses of ascorbic acid (acting as a reducing agent) shift the equilibrium back towards normal.

The work of Gibson has shown that the disease is due to an enzyme defect in the red blood cells. In blood taken from patients, the oxidation of glucose or lactic acid, coupled with reduction of Met-Hb, is much slower than normal. Addition of the dyestuff methylene blue, which can act as an artificial catalytic carrier both *in vitro* and *in vivo*, raises the glucose utilisation to normal but does not restore lactic acid oxidation. Methylene blue apparently opens up a pathway of glucose oxidation not involving lactic acid as an intermediate, probably by permitting stepwise oxidation of the 6-carbon chain, catalysed by coenzyme II and diaphorase II. The reaction between diaphorase II and Met-Hb is believed to be too slow to be effective unless catalysed by methylene blue and therefore, in normal people glucose utilisation coupled with Met-Hb removal is believed to be mainly via lactic acid, the oxidation of which is catalysed by coenzyme I and diaphorase I. The reason this path is ineffective in the patients is that there is a shortage of diaphorase I (a flavoprotein enzyme) in their red blood cells. This shortage was demonstrated by direct assay of diaphorase I in the blood of all seven patients who were tested. The values were in every case lower than those of any of the sixteen normal bloods used for comparison. Addition of excess of diaphorase I restored full activity.

The oxygen dissociation curve of the blood in the patients was found to be shifted to the left, i.e. the blood parted with its oxygen less readily than normal. This, coupled with the large amount of pigment present in the abnormal, non-functional state, makes it surprising that the patients as a whole were able to lead active, energetic lives. The compensating polycythaemia present in the more severe cases may help to explain this.

The disease is apparently due to a mutation of the gene responsible for synthesis of the flavoprotein diaphorase I. In all three families studied the disease appeared to be inherited as a recessive Mendelian trait though pedigrees have been published by Codounis and by Baltzen which suggest that it may sometimes behave as a dominant. Quantitative studies on the blood of relatives of our patients have given no evidence for the presence of detectable genetic carriers. Treatment of the patients (which was successful in all cases) consisted of large daily doses of ascorbic acid continued indefinitely, preferably supplemented by a single dose of methylene blue after the first few days.

THE LOWER CARBONIFEROUS ROCKS OF NORTH-WESTERN IRELAND

At the Belfast Meeting of the Association, Section C (Geology) devoted the morning of Friday, September 5, 1952, to a discussion on the Lower Carboniferous rocks of north-western Ireland. Contributions were made by Prof. T. Neville George, Dr. D. H. Oswald, Dr. Ian M. Simpson, Mr. Peter Padget, and the late Prof. L. B. Smyth. The digest of the contributions which follows has been prepared by Prof. T. Neville George of the University of Glasgow.

Regional Palaeogeography

Rocks of Avonian age are widespread in Ireland, but only in a few areas are they known in detail. Douglas's pioneer work in Clare has been followed by that of Smyth and Turner in Dublin, Wexford, Waterford, and Cork; but the central and northern outcrops have only recently received attention and information on them is as yet mainly unpublished. Turner's recent compilation on zonal stratigraphy, highly instructive as it is, serves to show how much work remains to be done.

Nevertheless, it is already evident that the floor of ancient rocks on which the Carboniferous beds rest was stratigraphically varied and topographically uneven at the first advance of the Avonian sea. In southern Ireland, the succession compares fairly closely with that of South Wales, and there was transition from Devonian into Cleistoporan beds. Farther north, however, the Lower Palaeozoic oldlands gave rise to an archipelagic environment, progressively drowned with continuing subsidence, that tended to limit sedimentation to more or less isolated troughs until Viséan times were well advanced. The Carboniferous rocks therefore display strong overstep across the old foundation, and strong internal overlap as the higher zones extend over progressively wider tracts than the lower.

Of these insular oldlands the Leinster massif has long been considered an extension of the Welsh St. George's Land. In some degree it separated the sub-geosynclinal sediments of the southern outcrops from the 'basin' deposits of Dublin, much as St. George's Land and the Mercian Highlands separated the South-Western Province from the comparable 'basin' deposits of the English Midlands. Farther north the Longford–Down massif, flanked on the north by the continuation of the Southern Uplands Fault, formed a similar barrier to sedimentation; and had its complement on the west in the Galway–Mayo massif.

The Carboniferous rocks of north-western Ireland were laid down beyond the Southern Uplands Fault. In part they occupy the down-warped equivalent of the Midland Valley of Scotland, lying, particularly in Fermanagh, between the Lower Palaeozoics of Cavan–Armagh on the south and the Old Red Sandstone of the wide Tyrone outcrop on the north. As the rocks of the Clogher–Slieve-Beagh syncline they have been described by Padget.

Westwards beyond Carrick the Southern Uplands Fault is not readily discerned, but the periclinal arch of the Curlew Mountains brings up pre-Carboniferous rocks and proves that in the heart of the down-warp the Avonian rocks rest on Old Red Sandstone and Lower Palaeozoic rocks no less transgressively than in the Longford country. The down-warp is flanked on the north by the Irish extension of the Highland Boundary Fault. This may be identified on the coast near Cushendun. It then emerges from beneath the young rocks of the Antrim plateau, and can be followed for many miles westwards beyond Omagh, where the Castle-Archdale Fault

is its continuation and the Cool Fault an associated structure. The flanking faults of the Ox Mountains, running to the coast of Mayo in Clew Bay, are parts of its system. Between the Curlew Mountains and the Ox Mountains, structural equivalents of the Clogher–Slieve-Beagh syncline are well developed in the Belcoo–Lough-Allen country and near Castlebar.

The Highland Boundary Fault and its offshoots were, however, no complete barrier to the Carboniferous sea, the waters of which spilled over and advanced northwards into Tyrone and Donegal probably in Tournaisian, certainly in Viséan, times. In this ground the Carboniferous sea drowned a peneplained surface of mainly metamorphic rocks, and any beds of Old Red Sandstone that may originally have been present were removed by pre-Avonian denudation. It is possible, however, that the contrast offered by the thick Old Red Sandstone of the Fintona country implies that the Highland Boundary Fault was an effective limit to Old Red sedimentation on the north.

The Avonian strata accumulating on the north flank of the Fault occupied troughs in the metamorphic foundation ; and conceivably at the maximum extension of the Avonian sea the greater part of Donegal and Londonderry was buried : the outlier north of Newton Stewart is an obvious link with the outcrops running to Lough Foyle, and the small remnant of basement conglomerate capping Slieve League is a hint that perhaps even the mountain summits of Donegal may have been submerged at maximum subsidence.

The regional structure implies the development of considerable down-warp on the north flank of the Highland Boundary Fault—a down-warp that is expressed along the whole tract between Omagh and Mayo. It is possible that the present-day outcrops reflect in part the initial structural features, at least in Tyrone where the Omagh–Pettigo syncline, described by Simpson, carries much thicker sediments than the equivalent downfolds in Donegal. The Ox Mountains formed an elevated tract marginal to this trough, and it appears that their anticlinal form was actively growing during Avonian times. Oswald's work between Sligo and Ballyshannon has brought out clearly the great thickness of sediments accumulating in the flanking down-warp. The Donegal syncline is similar in general form to the Omagh-Pettigo syncline. Its basal beds indicate strong transgression across a metamorphic floor : some of the present-day land-forms suggest stripped surfaces from which the Avonian rocks have been eroded, and cliffed margins against which

Fig. 1.—Outline map of the geology of the North of Ireland.

littoral deposits are banked are visible in places.

Stratal Succession

The lithology of the rocks reflects the essential conditions of sedimentation. The earliest beds consist of coarse-grained conglomerates and sandstones, highly variable in development, which become finer-grained in upward succession and are succeeded by calcareous shales and limestones. Over most of the ground the predominant facies is calcareous, though there are sandy intercalations at several horizons. This phase is abruptly terminated by the oncoming of the so-called 'Yoredale' Beds, which are followed with apparent conformity by Namurian coal-bearing sediments.

The basal conglomerates and sandstones are highly varied in thickness and in constitution. They are often extremely coarse—boulder beds in places—shore deposits derived from more or less immediately neighbouring sources, with pebbles resting in a matrix of shore sand. Of all the strata they reveal most clearly the occurrence of overlap. They are best seen in the Omagh syncline and in the down-faulted synclinal outlier between Newton Stewart and Lifford. They are also well exposed in the western outcrops of the Donegal syncline, notably in the cliff sections between Killybegs and Muckros. In Mayo the conglomerates and associated sands cover scores of square miles of the ground west of Killala Bay.

The limestones fall into two or three main groups which have received deceptively simple names (Lower Limestone, Calp Limestone, Upper Limestone) given on local lithological successions that in fact vary markedly from place to place. They are often shaly limestones, or thin-bedded limestones with shale partings; and in their typical development, as on the coast of Sligo, they carry thick intercalations of shale (Lower Calp Shale, Calp Shale) that have been equally misleading in the past as guides to correlation. A sandstone (Calp Sandstone) strongly developed in the middle of the limestone series has hitherto been mistaken in the Omagh syncline for 'Yoredale' sandstone.

The abrupt lithological change at the top of the calcareous series is probably a mark of strong non-sequence or unconformity. The shales and sandstones are miscalled 'Yoredale,' for they differ from the true Yoredale-type sediments in being almost without limestone bands and without corals, and in yielding an abundance of goniatites in their lower part. Though differing in notable petrographic characters they approximate more nearly to rocks of Pendleside facies. Their succession has been most completely worked out by Padget on Cuilcagh, south of Belcoo.

The Lower Conglomerate and Sandstone Groups

The conglomeratic basement strata are best known from the Omagh syncline, where Simpson has recorded coarse boulder beds reaching a thickness of several hundred feet in the neighbourhood of Omagh. The lowest eight or ten feet are often strongly red-stained and look not unlike Old Red Sandstone: they may indicate some re-working of arid-climate subaerial breccias. Conglomeratic bands are found in succeeding sandstones that reach a thickness of not less than 2,000 feet near Omagh, and possibly as much as 4,000 feet in the outlier north of Newton Stewart. This group, the Omagh Sandstone Group, is a mixed series of grits, sandstones, and pebble-beds with thin intercalations of grey shales and impure limestones. Some layers are highly carbonaceous, and some look like seat-earths. Fossils in the group are neither abundant nor varied, and are not helpful in dating the beds: but the few brachiopods (including *Camarotoechia* cf. *mitcheldeansis*) suggest a Tournaisian age.

The strata succeeding the Omagh Sandstones are also arenaceous, but they differ notably in their generally finer grain, the abundance of their clastic felspars, and the relatively common occurrence of calcareous bands. They are separated by Simpson as the Claragh Sandstone Group, and reach a thickness of about 3,800 feet. While the main source of the detritus in the Omagh Sandstones appears to have been the local Dalradian rocks, the arkosic grits of the Claragh Sandstones most probably were

derived from the Moine granulites to the west which also carry as a possible felspar-source thick veins of pegmatite. The fossils of the Claragh Group, though more common than those of the beds underlying, are not zonally diagnostic : on the whole they suggest a Tournaisian age, the algal layers perhaps pointing to correlation with C_1 of northern England.

From Omagh westwards to Lough Erne the trough of sedimentation shallowed markedly, and both sandstone groups show rapid reduction in thickness. Near Pettigo internal overlap causes the disappearance of the Omagh Sandstone Group, and the Claragh Sandstones, rather coarser-grained than in their eastern outcrops, rest with a basal conglomerate on the Dalradian foundation. They are also much reduced in thickness, and although this is partly brought about by the Pettigo Fault, normal junctions in the Belleek country show that the conglomeratic basement beds there are no more than about 15 or 20 feet thick, being followed immediately by dolomitic limestones at the base of the Lower Limestone. At Ballyshannon the basement beds have a dolomitic matrix, and probably lie at a higher horizon than the top of the Clogher Sandstone Group, which is completely overlapped.

The strong coarse basal conglomerates at Muckros, reaching about 100 feet in thickness and containing large beach boulders, are probably at a still higher horizon, for they are followed by thin limestones and calp shales lying within the Lower Limestone Group, only a few hundred feet below the Calp Sandstone. It is not unlikely that the basement beds of the wide outcrops on the northern flanks of the Donegal syncline are also at diachronously high horizons.

In the Clogher valley the earliest Avonian deposits, resting unconformably on Old Red Sandstone, are conglomerates at a horizon only some 300 feet below what appears to be a thin representative of the Calp Sandstone.

The Lower Limestone and the Lower Calp Shale

The Omagh and Claragh Sandstone Groups, though marine in origin as indicated by the relatively rare fossils they contain, are not typical open-sea rocks ; and in a number of their characteristics they approximate to deltaic and estuarine sediments. In some degree they look not unlike many of the beds of the Calciferous Sandstone series of Scotland (though the cementstone facies is not prominent in them).

The succeeding beds, however, to a thickness in places of nearly 4,000 feet, are typically neritic limestones and shales, abundantly fossiliferous, obviously belonging to the Carboniferous Limestone. Their generally uniform character and widespread development reflect a regional subsidence and a relative deepening of the sea ; and they mark a marine transgression. Significantly, they yield fossils in their lowest beds suggesting an Upper-Caninian age, when Viséan transgression occurred not only elsewhere in Ireland but also on the flanks of the Lake District and in the South-Western Province (notably after the break recorded in the mid-Avonian unconformity).

The first member of this calcareous series is the so-called Lower Limestone. With more or less constant thickness of about 1,000 feet, it can be followed round the western outcrops of the pitching Omagh syncline, it forms a broad outcrop in the Belleek country whence it runs to the sea at Ballyshannon, it flanks the greater part of Sligo Bay, and it extends into much of the central tracts of the Ballina syncline. In the Donegal syncline it appears to be relatively thin, but retains its main features. In general characters it is a series of thin-bedded limestones with limy shales, many of the beds being richly organic-detrital—some indeed being coral or brachiopod limestones.

On the eastern flanks of Lough Erne, limestones are the dominant constituent of the member ; but across the lake, along the valley of the Erne river towards Belleek, beds of shale, the Lower Calp Shale, develop in the upper part and reach a thickness of several hundred feet. Their erosion contributes notably to the local topography, and along the back slope of the low escarpment formed by the Lower Limestone they fall to the hollow at the foot of the second (and principal) escarpment running from Lough Erne to Lough

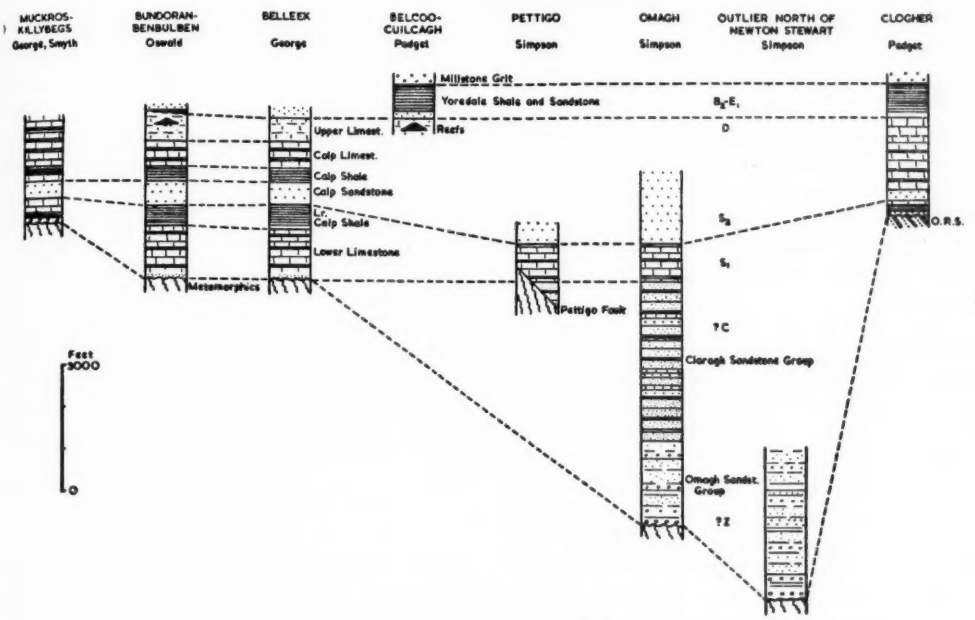


Fig. 2.—Comparative sections in the Avonian Rocks of North-Western Ireland.

Melvin. They reach the coast at Bundoran, and are called by Oswald the Bundoran Shales. Highly calcareous, with thin organic-limestone ribs, they are perhaps even more richly fossiliferous than the underlying Lower Limestone: in Bundoran Bay the etching of the fossils by the sea makes the cliffs one of the most prolific collecting-grounds in Ireland. The Bundoran fauna was first recorded by Wright over forty years ago, when he showed that the association of large caniniids with species of *Lithostrotion* suggested a lower Viséan (S_1) age. The facies is that of a zaphrentid phase, the great abundance of corals having deceived Clark, working on the south-west flanks of Sligo Bay, into a belief that he was dealing with beds of Zaphrentidan age. There are perhaps differing proportions of the respective species in the Lower Limestone and the Lower Calp Shale, with colonies of *Lithostrotion* and *Michelinia* more common in the former, zaphrentids and *Chonetes destinezi* more common in the latter; but the species assemblages in the two members are virtually the same.

In the Killybegs country the basal conglomeratic beds are followed by shales like the Bundoran Shales, with a similar abundant fauna. They are overlain by limestones of Lower Limestone type, which in turn underlie Calp Sandstone. It is evident therefore that facies changes are significant in comparatively short distances in this calcareous group; and lithology (with its terminology) is not a safe guide in correlation. Similarly in the Clogher area the Belelastera Shales, not quite so strongly argillaceous as the Bundoran Shales, are overlain by thin limestones underlying Calp Sandstone, and can only be homotaxially equivalent to the Bundoran Shales proper.

The Calp Sandstone

A recurrence of the sandstone facies, the Calp Sandstone, is well marked over the greater part of north-western Ireland. The rock-types are not unlike those of the Claragh Sandstone Group—felspathic sandstones with some pebbly grits and hard sandy limestones—though they are usually finer-grained and more quartzitic. Commonly the felspar grains suffer decay to clay residues, and the disintegration of the matrix makes the rock very friable. Elsewhere the calcitic bond may be so strong as to permit the use of the beds as good building stone. Mica is abundant in many layers, and on the western shores

of Lough Erne the beds are strongly fissile siltstones. The frequent occurrence of current bedding suggests shallow water, and graded bedding points to sharp changes in the velocity of transport ; and while the rocks are mostly typically marine there was some reversion to deltaic conditions, indicated by some of the lower beds in the Sandstone, with occasional layers being carbonaceous and plant-bearing.

The transition from the underlying shales and limestones is sometimes abrupt, but more usually there is a gradual passage with a proportionate increase in sandy layers upwards. There is a corresponding reduction in fossil content, and most of the Calp Sandstone is unfossiliferous. The interbedded sandy limestones, however, yield assemblages comparable with (but much less rich than) those of the underlying groups, including species of *Lithostrotion* and *Zaphrentis* ; and brachiopods and lamellibranchs are occasionally common. Specially significant is Simpson's discovery of *Davidsonina* [*Cyrtina*] *carbonaria* in the group near Kesh ; this, with the not infrequent occurrence of *Composita*, is evidence of an Upper-Seminulan age for the Sandstone, and comparison with the Fell Sandstone of England may not be too far-fetched.

The Calp Sandstone reaches its greatest thickness in the heart of the Omagh syncline, where not much less than 2,000 feet occur. In this ground it is relatively felspar-poor, and relatively coarse-grained. Westwards to Lough Erne it thins rapidly and becomes finer-grained : near Kesh it is little more than 500 feet thick, possibly because it is not completely preserved. In the Belleek country it forms wide outcrops in the lower ground of the left bank of the Erne ; and it reaches a thickness of about 600 feet between Lough Erne and Lough Macnean. A similar thickness is exposed in the cliffs west of Bundoran (where the beds are richly felspathic), and on the northern flanks of the Ox Mountains ; and the thickness is probably not much less in the Donegal syncline (where, however, minor faulting breaks the succession). But in the Clogher valley the beds apparently equivalent are only some 250 feet thick, though the only fossils recorded by Padget are crinoid fragments.

The great variation in thickness of the Calp Sandstone may no doubt in part be due to differential rates of sedimentation, as the varying grain-size suggests. But principally it appears to be due to lateral changes of facies. If the Pettigo and Ballyshannon limestones are correlative, the absence of well-developed Lower Calp Shale in the Omagh syncline may point to a passage of the argillaceous beds into the arenaceous beds of the lower part of the Sandstone. The onset of the sandy phase then advanced from north-east to west and south-west, and affected the ground south of the Castle-Archdale Fault only very late in Sandstone times.

The Calp Shale and Calp Limestone

The Calp Sandstone occupied only an interlude in the general sedimentation sequence of calcareous shales and shaly limestone that characterised the greater part of Viséan times in north-western Ireland. The succeeding Calp Shale and Calp Limestone repeat the essential facies of the Lower Limestone and Lower Calp Shale, and in isolated outcrops the older are sometimes only with difficulty distinguished from the younger strata.

Together, the Calp Shale and Calp Limestone, attaining a thickness of rather more than 1,000 feet, show a progressive increase in the proportion of limestone in upward succession. The lower strata are almost wholly shales, though they carry thin limestone ribs or layers of limestone nodules. In the upper strata the shales become increasingly calcareous and nodular and finally form little more than thin partings between the limestone bands. With such gradual transition only an approximate division is possible between the two members of the group. Indeed the divisions break down in places where there is lateral passage ; thus Oswald has not been able to distinguish a separate Calp Limestone on the flanks of the Ox Mountains, while the Calp Shales are relatively suppressed in the Clogher syncline.

The Calp Limestone, though rarely forming the scarp crest, contributes to the scarp walls of the long front forming the west flank of Lough Erne from near Belleek

to Belmore Mountain and beyond. Its sheer faces fall to the more gently sloping grassy or wooded ground of the Calp Shale, the topographic relations being such as to give rise to frequent large-scale landslipping. A similar hill-profile characterises the front of the Dartry Mountains and the Belbulben range, and the trough-walls of Glencar and Glenade. In the Donegal syncline, as near the Ox Mountains, there is a less clear lithological distinction between the two members, the Calp Limestone not being so strongly calcareous ; and the regional topography is more subdued than on the southern flanks of Sligo Bay.

The conditions of deposition of the rock-group—shallow-water open-sea organic-detrital mud-zone conditions—were very like those of the Lower Calp and the Lower Limestone ; and the group is richly fossiliferous (the Calp Shale distinctly more so than the Calp Limestone) with abundant corals, brachiopods, and polyzoans. Since it rests on Calp Sandstone it falls into a zone certainly not older than S_2 ; yet its special facies is revealed in a fauna misleadingly like that of the Caninia Zone. The presence of abundant *Lithostrotion* serves to prove Viséan age, and certain productid species indicate a high horizon ; but the most common fossils are zaphrentids and large caniniids scarcely distinguishable from those of the Lower Limestone and Lower Calp Shale. The simple corals are accompanied by common specimens of *Leptaena*, *Tylothyris*, and *Pustula* that in the South-Western Province would point strongly to Tournaisian horizons, and the general facies is closely like that of C_1-C_2 in Pembrokeshire and Gower.

Nothing could indicate more clearly the inherent limitations of Vaughan's zonal scheme when carried too far away from its native country. The whole sequence from the Lower Limestone to the Calp Limestone is, apart from the minor interruption of the Calp Sandstone, in zaphrentid phase—one moreover in which the species assemblages show little substantial change throughout a thickness of over 3000 feet. Work by Oswald suggests that significant statistical differences in communities of *Caninia* may be a means of distinguishing early and late sediments, but they are relatively minor, and laborious to apply. This persistent limestone-shale facies had a negative effect in excluding many of the characteristic fossils of the zone-range from the area : notably rare or absent are carcinophyllid corals and *Dibunophyllum*—the latter genus being uncommon in the Calp Limestone at Clogher and quite unrecorded at that horizon farther west.

The Upper Limestone

The Upper Limestone, about 500 to 700 feet thick, differs from the beds below in its relatively massive character and in the absence of shale bands. It is a pure rock, usually granular in texture, with much crinoid debris. The conditions of sedimentation suggested are those of a shallow-neritic clear-water shelf sea, with terrigenous detritus reduced to insignificant proportions presumably as a result of mature peneplanation of the hinterland.

The Upper Limestone carries abundant chert in nodular and tabular layers, and erosion in places results in the pavements of limestone being strewn with vast numbers of chert ' pebbles.' While some parts of the Lower Limestone succession are cherty, and carry silicified fossils, such a richly siliceous development is normally absent from the Carboniferous Limestone of the area. The origin of the (secondary) chert is problematical, but it is perhaps significant that the Upper Limestone is immediately overlain by the strongly siliceous ' Yoredale ' beds.

The most abundant fossils in the Limestone are species of *Lithostrotion*, but large caniniids also occur, and zaphrentids are not uncommon.

Perhaps the most outstanding feature of the Upper Limestone, however, is the development of reef structures. In the neighbourhood of Belcoo and Cuilcagh the reefs erode to form characteristic knolls, and there is close topographical similarity with the Craven reef country. The reef limestone is massive, unbedded or obscurely bedded, and tectonic origin is not indicated by internal structure. It is usually very fine-grained, a mudstone partly perhaps of chemical origin laid down under calcite-pan conditions (though there is never any suggestion of a ' lagoonal ' environment comparable

with that postulated by Dixon for the 'Modiola phases' of South Wales); and it is usually without chert. South-east of Sligo similar reefs are found; but of more spectacular occurrence are reefs described by Oswald as having the form of enormous lenticles covering several square miles and sometimes many hundreds of feet thick. On Benbulben they are polyzoan reefs, ill-bedded, running as sheets between normal layers of Upper Limestone. Farther south they give rise to bare cliff-scarps or hill-crests, irregular in topographic form, that dominate much of the landscape on the north front of the Ox Mountains: it may be that the anticline in metamorphic rock, actively arched up during sedimentation, contributed to the establishment of appropriately reef-forming conditions.

The reefs in places yield abundant fossils, though much of the rock is completely unfossiliferous. Occasional corals include zaphrentids and caniniids, but also *Dibunophyllum* and *Palaeosmilia*. Brachiopods, particularly rhynchonelloids, are the most abundant forms. Of unusual interest is the common occurrence of blastoids. Near Sligo goniatites are fairly common: they belong to the *Beyrichoceras-micronotum* group, and suggest not a Waulsortian but a B_2 age.

The 'Yoredale' Shale and Sandstone

The impropriety of using the term 'Yoredale' has already been commented on, but in the area where the beds have been most recently studied—Cuilcagh—Padget has retained the term.

Shales are dominant in the succession, the sandstones being variable in both development and horizon. The beds rest with an abrupt junction on the Upper Limestone, and intervening uplift and intensified hinterland erosion must be inferred. There is no definite evidence of discontinuous sedimentation in most areas, but on the southern flanks of the Dartry Mountains Oswald has found the lowest bed of sandstone to overlap the thin underlying shale and to rest transgressively on a reef with knoll form belonging to the Upper Limestone.

Details of the palaeontology of Cuilcagh have recently been published by Padget, and it suffices to say that the 'Yoredale' beds are mainly Cracoean (B_2) and Bollandian (P) age, and range up into lower Namurian (E). The major stratigraphical break thus lies within the Avonian succession, the upper beds of which run with the 'Millstone Grit' and not with the Carboniferous Limestone.

Structural Relations

Avonian sedimentation in north-western Ireland displays unusual features in its relation to the underlying foundation. Everywhere there is strong unconformity at the base, and even at those localities where Old Red Sandstone occurs, as in the Clogher valley, the Carboniferous overstep is no less marked than elsewhere. In the Enniskillen country the thin basement beds cannot be much older than late S_1; and the Tournaisian is wholly absent. This contrasts with the relations in the Midland Valley of Scotland, where transition from Upper Old Red Sandstone to the Calciferous Sandstone series is gradual and unbroken (however doubtful may be the true ages of the beds). While it is unquestionable that the Midland Valley rift continued south-westwards into Ireland, and controlled Avonian sedimentation in the Clogher–Slieve-Beagh syncline, it is therefore no less true that the relative effects of the Southern Uplands Fault were markedly different in the two countries.

The nature of the Highland Boundary Fault is even more abnormal. The effective downthrow of the Fault in the Midland Valley, produced by repeated movement before, during, and after Carboniferous sedimentation, is consistently to the south, and of the order of many thousands of feet. In Ireland, however, it is highly variable in its effects, and its downthrow is not consistently to the south. The Castle-Archdale Fault particularly well illustrates this variation. So far as the relations of metamorphic rocks and Old Red Sandstone are involved it behaves in the normal fashion of the Highland Boundary Fault, with the younger rocks forming wide outcrops on its southern flanks. But its effects were reversed by the post-Carboniferous movements, for it throws down the Avonian

rocks to the north. Similarly the main Ox-Mountain Fault throws down the limestones of the Sligo syncline some thousands of feet to the north.

Moreover these abnormal relations were established in Avonian times. The scarp of the Highland Boundary Fault was in Scotland a strong topographical control on sedimentation throughout Upper Palaeozoic times, and the overstep of Old Red Sandstone and Carboniferous rocks northwards across it onto the Highland Dalradians was never great : the Highlands indeed being then high lands as they are to-day. The expected analogous scarp in Ireland was insignificant or non-existent. It had no control on sedimentation in the Belleek–Belcoo country, where the continuity of the Carboniferous rocks across the plane of the fault is unaffected in succession or thickness. In this ground, too, even the post-Avonian movements resulted in negligible fracture, the line of the Castle-Archdale Fault—a fault having a throw of at least 900 feet near Kesh—is directed towards an almost unbroken cliff of Upper Limestone on the western shores of Lough Erne.

The anomalous relations are at maximum on the south flank of the Sligo syncline, where downthrow along the (northern) Ox-Mountains Fault was towards the syncline during times of Avonian sedimentation. The equivalent of the Midland Valley rift was thus effectively in this ground a Carboniferous horst—at least that part of it running along the axis of the Ox Mountains.

Finally, the Avonian rocks of the Dalradian block of the Scottish Highlands are thin or absent, and the tract was a positive element controlling sedimentation throughout Upper Palaeozoic times. The equivalent Dalradian-Moinian block in Sligo–Donegal–Tyrone on the other hand was a tract of widespread Avonian subsidence and down-warping, and relative to the ground to the south acted in some degree as a negative crustal element : the greatest accumulations of Avonian sediments of north-western Ireland, estimated to have been not less than 8,000 feet thick before erosion subsequently removed some of them, were deposited in the Omagh syncline well inside the ' Highland ' line.

TRANSHUMANCE IN IRELAND[1]

by

Mrs. J. M. GRAHAM

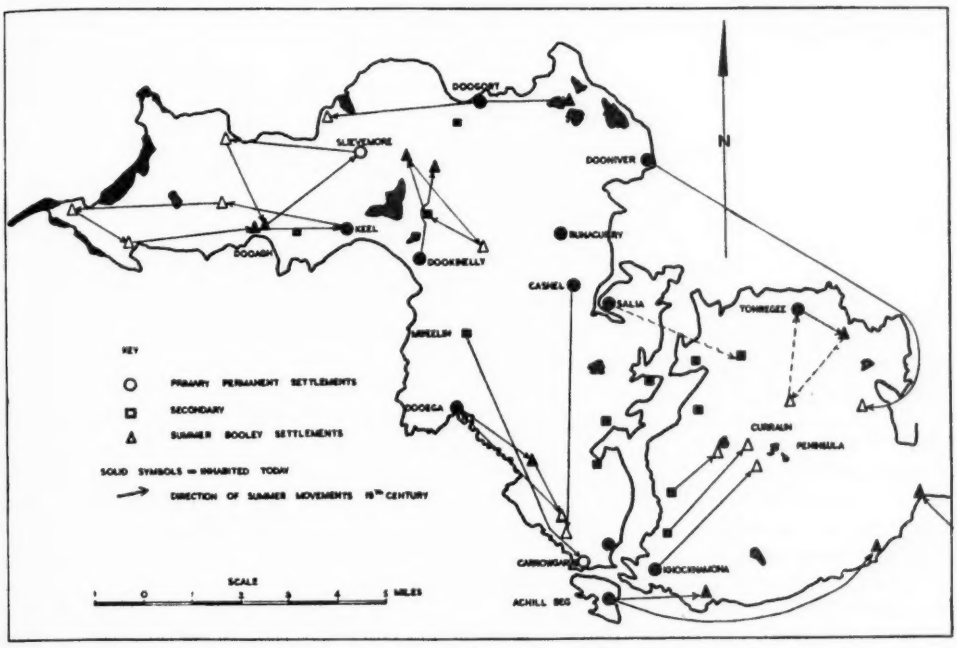
In countries where, for reasons of relief and climate, there are extensive areas of land agriculturally valuable during one season of the year only, rural communities have developed a form of farming which allows them to use the seasonal land. In most areas it is additional summer pasture. The movement of livestock accompanied by some members of the community to temporary residence on such seasonal pastures is known as transhumance. Apart from modifications due to variations in environment, Irish transhumance belongs to the North European or Alpine type, no doubt more familiar in the Alps, Norway or Sweden where it is more widespread and still survives. The common physical factor throughout is the occurrence of summer pastures on mountains or bogs, or in forests, which in winter are useless because of cold and snow, or because of rain and lack of adequate drainage. Throughout the group, cattle (especially dairy cows) are the dominant livestock, though sheep and goats are commonly kept as subsidiaries. Transhumance in these countries is part of a family subsistence economy and not, as in many Mediterranean countries, the specialised occupation of a few families. Pressure of population on limited cultivable land, together with a closed subsistence economy, has led the communities to practise transhumance, and the release of such pressure allows the practice to decline in importance and extent. In Ireland it has finally disappeared.

Ten years ago a summer visit to the village of Slievemore on Achill Island, off the west coast of County Mayo, would have given a glimpse of the last transhumance in Ireland. Among the many ruined and deserted houses on the mountain side were some occupied by old women and occasional children who looked after their few cows grazing on the mountain. Some from Dooagh were there in their own right, others from Valley and Dooniver had to rent both houses and grazing from Dooagh people. To-day the houses are cow-sheds and sheep-pens, and if any dairy cattle still graze there in summer the owner or one of his family come twice a day to milk them.

For Achill Parish, nineteenth century records and reports provide a picture of the system under more favourable conditions. A large part of the island is mountain grazing or bog, both of which, if usable at all for agriculture, are suitable only for summer grazing. Permanent settlement to-day fringes the island and much of the cultivated land has been won with hard labour from the bog. Most of the uncultivated land is common again to-day, as it was for centuries before grasping landlords alienated it for their own stock-farming in the mid-nineteenth century. The farmers of a townland shared the common grazing in 'sums,' each farmer holding a number which varied according to the amount of arable land he held. A full-grown cow was the basic unit of a 'sum,' other animals were rated according to their grazing capacity. The rating varied in different parts of the country but a common one was 1 cow: 6 sheep : 12 geese with other ratings for different ages of animals. In the south of Ireland the name for such stints was 'collop' instead of 'sum.' Some similar form of grazing stint is very common in other parts of Europe.

During the early part of the nineteenth century the inhabitants of Slievemore, Keel, Dugort and Dookinelly sent their livestock to summer pastures a few miles away, in the charge of the girls of each family. They lived in rough oval or

[1] Paper delivered to Section E (Geography) at Belfast on Friday, September 5, 1952.

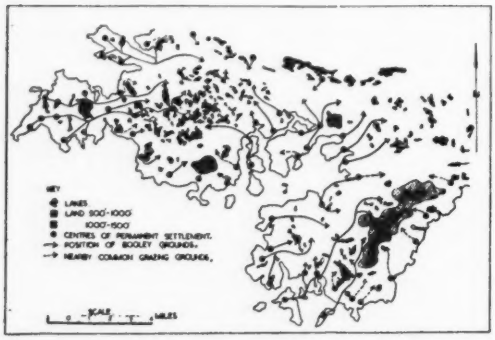


Map 1.—Achill Parish: Settlements and Transhumance.

square summer huts of stone and turf, roofed with bog timber and sods. They watched and milked the cows, churned butter and now and then took it back to their families. In some cases they moved on to other sites on their pastures when the grass at one place was exhausted. This movement to the summer pastures was usually made in May, from the first to the twelfth according to the weather and custom, and the return was at the end of October in time for Hallowe'en. At the time of the great 1845–6 famine a reversal was made in the Slievemore arrangement. The old permanent village was deserted for the summer village at Dooagh where the people could supplement their diet with sea and shell fish. Hence the more elaborate long-houses at the deserted village of Slievemore to-day, and Dooagh ownership of them and the grazing rights there.

Even this pattern of transhumance was not that at the height of the practice. Earlier, in the eighteenth century, and presumably before that (though no records exist for such a date), other settlements in the parish had summer sites and practised transhumance (Map 1). Where no mountain grazing was available in the vicinity, as at Dooniver, Achill Beg Island and the Clew Bay islands, the Corraun peninsula provided the essential summer pastures. Pressure of population and declining standards of living and numbers of livestock meant that these pastures had become permanently settled before the nineteenth century. The new settlements could have only common grazing on the nearby mountain and hence many had no summer settlements for transhumance.

Other isolated mountain districts of the west also provided the conditions necessary for the late survival of transhumance. In western Donegal an area of high mountains and widespread bog helped by this means to support a coastal population. In the south-west the summer settlements were several miles away but in the same parish. Farther north they were as much as ten miles away. In western Connemara extensive bog at under 200 feet provided the summering grounds (Map 2). Some coastal communities went on practising transhumance here until the late nineteenth century and the beginning of the twentieth, and there can still be found the ruins of the little stone huts which housed the dairy-maids. In Connemara the coastal fringe is densely populated but

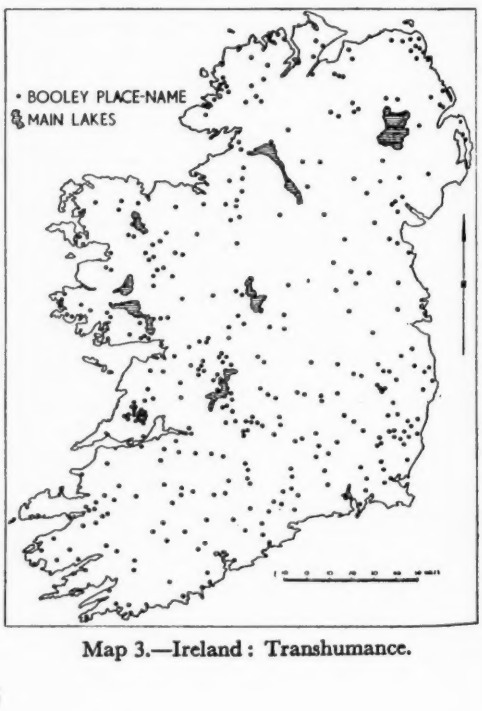


Map 2.—West Connemara : Transhumance.

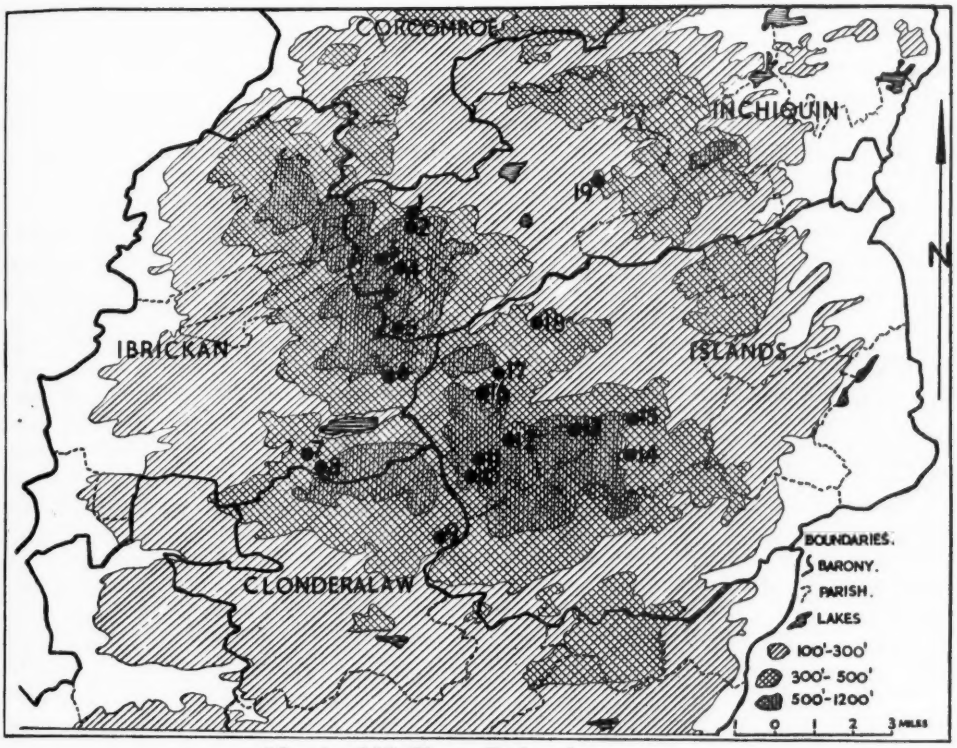
not all the settlements practised transhumance. Some had sufficient common grazing near by, so that although the cattle had to be kept beyond the open-field during the summer, the open-field being a concomitant agricultural feature, they were sufficiently close to be milked daily from the home farms. It was the completely settled and cultivated islands and promontories which made use of distant summer pastures and amongst which transhumance survived longest.

It is obvious from occasional reports of travellers in Ireland that the practice was once more common than the few surviving traditions would indicate. Among the Irish of pre-plantation Ireland cattle always occupied an important place in the economy. Pre-seventeenth century conditions were much more favourable for transhumance, except in the more densely settled lowlands of the east and south. It is difficult, however, to find information about what must then have been a common agricultural practice. A certain amount of information can be gleaned from a study of place-names. In Ireland since the sixteenth century transhumance has been known in English as ' booleying.' The Irish word ' buaile,' a cattle fold or milking place, has been anglicised to ' booley,' and the custom of moving to summer pastures has become ' booleying.' Variations of Irish ' buaile ' are not uncommon in place-names. If their distribution is considered with factors of relief, type of ground and date of permanent settlement it is possible to infer a wider distribution of transhumance. Though the Irish word means only a milking-place, and may therefore be applied to areas which have never seen transhumance, in mountain districts, where it is fairly common, the occurrence of a milking-place in areas not permanently settled until the nineteenth century, if at all, certainly indicates booleying. The distribution of such place-names (Map 3) shows that the custom was once practised away from the areas where traditions survive, especially amongst the mountain country of western and southern Ireland. Only its early disappearance, in the seventeenth century or before, is responsible for the lack of traditions and records.

Part of County Clare is an excellent illustration of this. In the south-west, in an area of Coal Measure sandstones and shales, an outcrop of gritstone forms a central highland of comparatively small extent, but rising steeply to 1,282 feet above lowlands from sea level to 300 feet. The upper part is still a stretch of bog and moor, rough grazing for store cattle, with here and there a little cluster of farms and fields. The lower slopes and the surrounding lowlands are now almost completely enclosed in fields and settled by dispersed farms. Of twenty-seven place-names in the whole of County Clare which contain a booley element, nineteen are concentrated on this mountain area



Map 3.—Ireland : Transhumance.



Map 4.—S.W. Clare: Booley place names.

1. Muingboleydee. 2. Boolyduff. 3. Boolynamiscaun. 4. Boolinrudda. 5. Boolynagreana Lough. 6. Knocknaboley. 7. Boleynavod. 8. Boleybeg Lough. 9. Boleynamweel. 10. Boolynaknockaun. 11. Booltiagh. 12. Boleyneaska. 13. Boleynabinna. 14. Boolynagleragh. 15. Boleybrien. 16. Slaghbooly. 17. Booltynabinnia. 18. Cloonbooly. 19. Boolavaun.

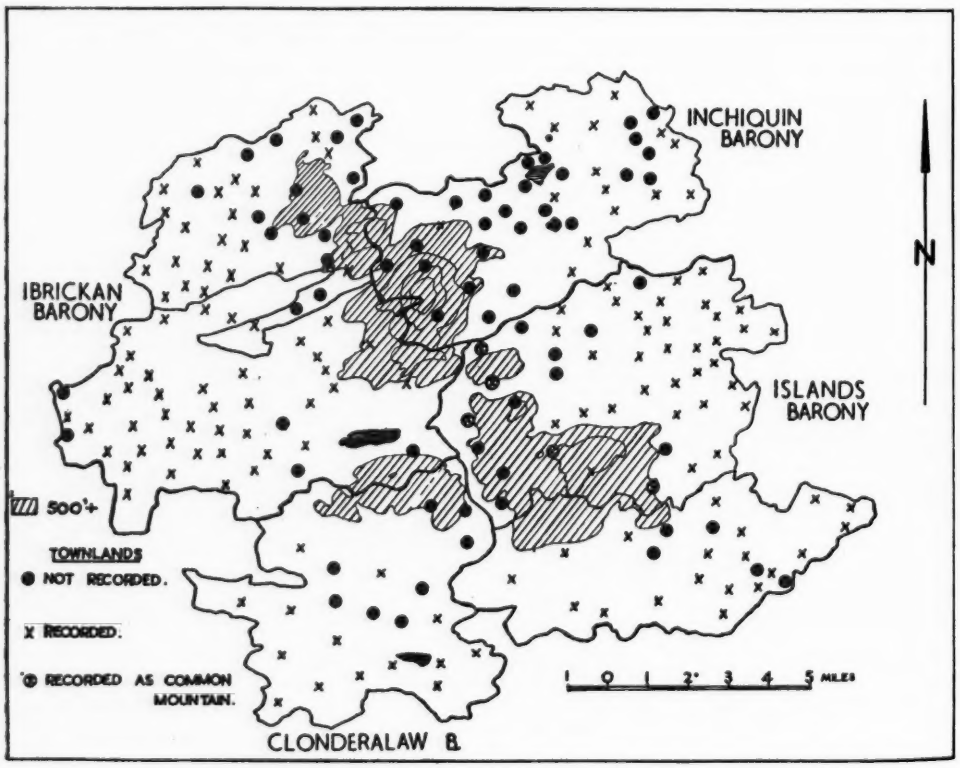
of the south-west (Map 4). Clearly this is more than coincidence. Although no traditions remain of the origin of these names, or of the practice of transhumance here, this mountain has obviously been at some time a centre of booleying for the surrounding lowlands. But because the mountain and bog were more amenable to reclamation, and the lowland belt wider and more fertile than in Achill, Connemara or Donegal, the summer pastures have been permanently colonised at a much earlier date, too long ago for traditions to survive.

Seventeenth-century records, made under the schemes for land confiscation, plantation and resettlement, show that by 1641 a large number of the present-day townlands of this district were already formed as small land units (Map 5). With very few exceptions the townland pattern of the lowlands was fixed by the mid-seventeenth century. On this central upland it was by no means complete. There was still a considerable amount of unenclosed common mountain. Also, certain of the mountain townlands which were already fixed were recorded as being entirely mountain grazing, common to townlands lying several miles away in the surrounding lowlands. The records have just caught the end of the transhumance phase, soon afterwards completely destroyed by increase of population and colonisation of the grazing grounds.

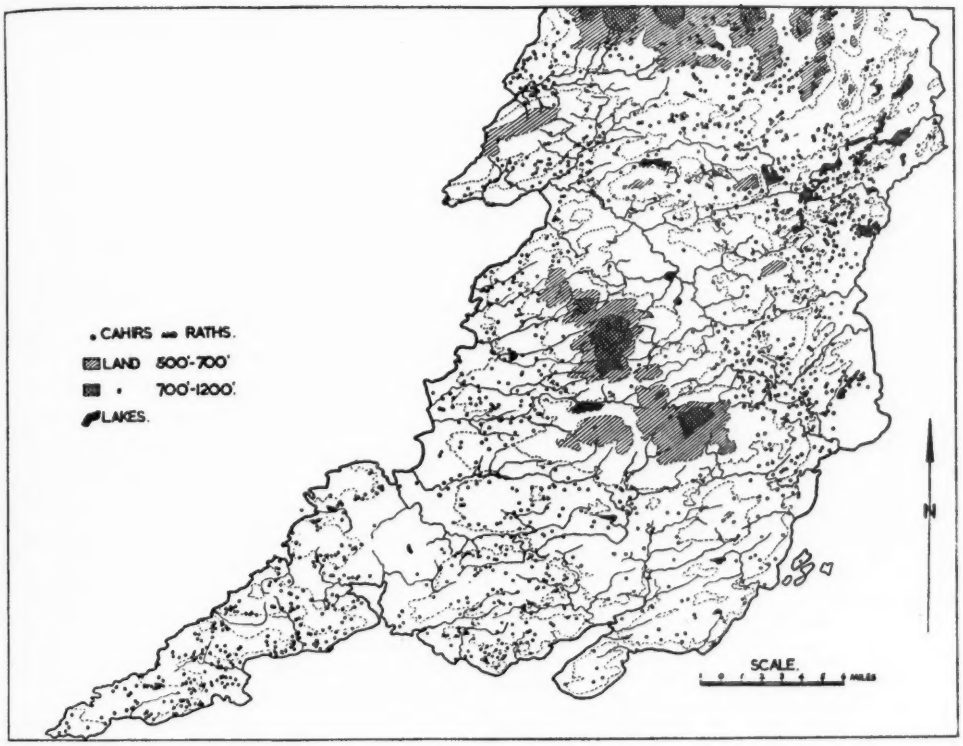
In this part of Clare the barony boundaries preserve the much older Irish territories, the tricha céts. These meet on this central mountain, each territory thus including a strip of land from lowland of coast or river to mountain inland. Each had thereby a variety of land types, including an area of summer grazing ground at some distance from the lowland, on which are left the booley names to indicate how it was used.

In Clare, too, there is certain evidence of the extent of settlement at an earlier period. During the Dark Ages and on into the Middle Ages many of the inhabitants of Ireland lived in dispersed farmsteads, circular in form, with wall base built of stone or earth or of both. This wall base remains to-day. The earthen ones are known as ' raths,' the stone ones as ' cahirs ' or ' cashels.' The few which have been excavated belong to the fifth to tenth centuries A.D. with an occasional one of earlier date. They are probably the homesteads of an extended family unit, and though their farming included cultivation it was dominated by livestock rearing. In Clare, where stone is abundant, cahirs can be counted in hundreds and they continued in use until the fifteenth century. A map showing their distribution supports the evidence of place-names and seventeenth century records (Map 6). This central mountain district was uncolonised except along a routeway, leaving an extensive stretch of summer pasturage, sufficiently distant from the home farms to require transhumance. At the same time the amount of permanent settlement was much greater than in western Donegal, Galway or Mayo, so that continued pressure of population here would destroy the practice at an earlier date than in those counties.

The same is true of other southern counties, especially of the mountainous areas. In some cases the early colonisation of summer pastures caused transhumance to deteriorate into a movement of store cattle and sheep in the charge of herdsmen. That the western districts of Ulster and Connacht were less advanced in settlement by the seventeenth century is noticeable from a comparison of contemporary records. Whereas in the south, as in Clare, almost all the present townlands were established and named, in the northern districts older and larger land units were still recognised and recorded. Small divisions were recorded as parts of larger units called ' Quarters.'



Map 5.—S.W. Clare : Townland development. Seventeenth century.



Map 6.—S.W. Clare : Distribution of farmsteads. Dark Age and Medieval.

These invariably included both lowland and mountain, the latter common pasture for all the farming communities of the Quarter. In some cases two or four Quarters are linked together, a reminder of still earlier and larger land units, and the mountain pasture is common to all.

The conclusion which is to be drawn from these seventeenth century records is that at least in the west of Ireland, where English interference with Irish customs was slight until that time, transhumance was an essential part of Irish agriculture. The old Irish land divisions were such as to provide a lowland population, which depended largely upon its livestock for food and wealth, with extensive mountain and bog land for summer pasturage. The distance of this from the cultivated land necessitated transhumance. When such lands became permanently settled, and this took place earlier in the south than in the north, the population had to depend more on cultivation than before, the numbers of animals they could maintain decreased, and these could be kept within easy reach of the farms. The need for transhumance was consequently destroyed, but the commonalty of mountain grazing remained. Where the practice, more or less modified, managed to survive to the end of the nineteenth and to the twentieth centuries, changing conditions of farming and the total destruction of self-sufficiency in rural communities have succeeded in making transhumance an historical aspect of Irish geography.

RESEARCH COMMITTEES, 1952–53

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICS AND PHYSICS.

Seismological investigations.—Dr. R. Stoneley, F.R.S. (*Chairman*), Lt.-Col. E. Tillotson (*Secretary*), Mr. E. F. Baxter, Miss E. F. Bellamy, Prof. P. G. H. Boswell, O.B.E., F.R.S., Mr. B. C. Browne, Dr. E. C. Bullard, F.R.S., Dr. K. F. Chackett, Dr. G. E. R. Deacon, F.R.S., Dr. A. T. J. Dollar, Rev. H. Norman Edge, Dr. A. E. M. Geddes, O.B.E., Prof. G. R. Goldsbrough, C.B.E., F.R.S., Dr. M. N. Hill, Mr. J. S. Hughes, Prof. Sir H. Jeffreys, F.R.S., Mr. E. N. Lawrence, Dr. A. W. Lee, Dr. A. O. Rankine, O.B.E., F.R.S., Rev. C. Rey, S.J., Dr. G. D. Robinson, Mr. H. V. Shaw, Sir Frank Smith, G.C.B., G.B.E., F.R.S.

SECTION C.—GEOLOGY.

To excavate critical geological sections in Great Britain.—Mr. W. H. Wilcockson (*Chairman*), Dr. G. Y. Craig (*Secretary*), Sir Edward Bailey, M.C., F.R.S., Mr. J. L. Begg, Mr. W. S. Bisat, F.R.S., Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. A. H. Cox, Dr. E. E. L. Dixon, Prof. W. G. Fearnsides, F.R.S., Prof. H. L. Hawkins, F.R.S., Prof. G. Hickling, F.R.S., Dr. R. G. S. Hudson, Prof. V. C. Illing, F.R.S., Prof. O. T. Jones, F.R.S., Dr. Murray Macgregor, Mr. T. G. Miller, Prof. L. R. Moore, Dr. F. J. North, Prof. F. W. Shotton, M.B.E., Dr. W. E. Swinton, Dr. F. S. Wallis, Prof. D. M. S. Watson, F.R.S., Prof. T. S. Westoll, Mr. T. H. Whitehead, Prof. W. F. Whittard, Prof. S. W. Wooldridge. **£30.**

To consider and report on questions affecting the teaching of geology in schools.—Sir Arthur Trueman, K.B.E., F.R.S. (*Chairman*), Dr. Mabel E. Tomlinson (*Secretary*), Miss M. A. Arber, Mr. A. Bray, Prof. A. H. Cox, Miss Gaynor Evans, Prof. W. G. Fearnsides, F.R.S., Prof. T. N. George, Prof. G. Hickling, F.R.S., Prof. D. E. Innes, Prof. D. Leitch, Prof. L. R. Moore, Prof. W. J. Pugh, O.B.E., F.R.S., Dr. K. S. Sandford, Dr. H. Dighton Thomas, Dr. A. K. Wells, Prof. A. Wood.

The collection, preservation, and systematic registration of photographs of geological interest.—Prof. H. L. Hawkins, F.R.S. (*Chairman*), Dr. W. S. Pitcher (*Secretary*), Mr. H. Ashley, Mr. G. M. Davies, Mr. W. G. Hardie, Dr. N. Holgate, Mr. G. S. Johnstone, Dr. A. G. MacGregor, Dr. F. J. North, Mr. J. Ranson, Mr. G. S. Sweeting, Prof. W. F. Whittard.

SECTION D.—ZOOLOGY.

To carry out dredging and similar investigations in Lough Ine and neighbourhood.—Prof. R. A. R. Gresson (*Chairman*), Prof. L. P. W. Renouf (*Secretary*), Prof. J. Bayley Butler, Dr. H. O. Bull. **£50.**

SECTIONS D, K.—ZOOLOGY, BOTANY.

Co-ordinating committee for Cytology and Genetics.—Prof. R. A. Fisher, F.R.S. (*Chairman*), Dr. J. L. Crosby (*Secretary*), Prof. F. A. E. Crew, F.R.S., Dr. C. D. Darlington, F.R.S., Dr. E. B. Ford, F.R.S., Dr. J. Hammond, F.R.S., Prof. T. J. Jenkin, C.B.E., Prof. K. Mather, F.R.S., Prof. L. S. Penrose, Dr. G. Pontecorvo, Dr. R. R. Race, Dr. P. T. Thomas, Dr. W. B. Turrill, Prof. C. H. Waddington, F.R.S.

SECTION E.—GEOGRAPHY.

To collect and record information on demography and seasonal activities in relation to environment in Inter-Tropical Africa.—Prof. A. G. Ogilvie, O.B.E. (*Chairman*), Mr. R. W. Steel (*Secretary*), Prof. S. J. K. Baker, Mr. K. Buchanan, Dr. R. J. Harrison Church, Prof. F. Debenham, O.B.E., Prof. C. Daryll Forde, Prof. B. J. Garnier, Dr. E. J. Howell, Mr. D. B. Mather, Dr. R. Miller, Prof. W. J. Varley, Prof. J. H. Wellington. **£5.**

SECTION H.—ANTHROPOLOGY.

To co-operate with the Torquay Natural History Society in investigating Kents Cavern.—Mr. M. C. Burkitt (*Chairman*), Prof. F. E. Zeuner (*Secretary*), Mr. A. L. Armstrong, Prof. V. G. Childe, Mr. A. G. Madan, Dr. K. P. Oakley, Mr. E. Pyddoke. **£10.**

To co-operate with a committee of the Royal Anthropological Institute in the exploration of caves in the Derbyshire district.—Mr. M. C. Burkitt (*Chairman*), Mr. A. Leslie Armstrong (*Secretary*), Dr. Arthur Court, Prof. H. J. Fleure, F.R.S., Mr. W. H. Hanbury, Dr. J. Wilfred Jackson, Mr. R. U. Sayce.

To consider the possibility of archaeological work on vacant sites in the city of Leicester.—Prof. I. A. Richmond (*Chairman*), Dr. D. B. Harden (*Secretary*), Mr. Philip Corder, Mr. A. Leslie Armstrong, Mr. D. T.-D. Clarke, Mr. K. D. M. Dauncey, Mr. R. G. Goodchild.

BIOLOGICAL SCIENCES IN BRITISH SCHOOLS

Report presented by a Research Committee of the British Association for the Advancement of Science at the Annual Meeting held in Belfast, September 3–10, 1952.

The Inception and Scope of the Committee

The Origin of the Present Committee

In 1928 the British Association published a report on *Animal Biology in the School Curriculum*. Since then substantial changes have occurred in British education in general, and in scientific, including biological, education in particular. The expansion of biological teaching in Secondary Grammar Schools, the Education Act of 1944, and the considerable effects which the demands of industry for scientific workers of all types have had upon the supply of science teachers in schools since 1945 should be noted.

In view of these changes Section K (Botany) of the Association suggested in 1949 that an enquiry into the present position of school biology would be desirable.

The Terms of Reference and the Composition of the Committee

The Council of the Association inaugurated the present Committee in November 1949, with the following terms of reference :—

> 'To consider the position of biology and rural science in the school curriculum and matters relating thereto.'

The Committee realised that all schools would require consideration.

The Committee consisted of :—

Professor L. J. Audus (Chairman), Professor of Botany, University of London.
Dr. L. M. J. Kramer (Secretary), Senior Biology Master, City of London Schools.
Mr. F. H. C. Butler, Director and Secretary, Council for Promotion of Field Studies.
Dr. H. R. Fletcher, Director, Royal Horticultural Society Gardens, Wisley.
[1]Mr. W. J. Heasman, H.M. Inspector, Ministry of Education.
Professor C. T. Ingold, Professor of Botany, University of London.
Professor H. W. Miles, Professor of Horticulture, University of London.
Dr. G. E. Newell, Reader in Zoology, University of London.
Mr. A. C. Penney, Headmaster, Bexleyheath County Boys' School.
Professor J. Walton, Regius Professor of Botany, University of Glasgow.
Mr. W. B. Yapp, Lecturer in Zoology, University of Birmingham.
Professor C. G. C. Chesters (Editor of Report), Professor of Botany, University of Nottingham.

The Methods of Working Adopted

It was considered that factual information must first be obtained from as many sources as possible, and that it should be presented together with constructive and realistic recommendations.

The Committee have held the view that, while it is desirable to take note of modern trends in the syllabuses, both of Examining Boards and those constructed by teachers for use in their own schools, no detailed investigation of them lay within the scope of the enquiry.

The Committee have been supplied with information from the various types of Authorities and Institutions acknowledged at the close of the Report.

The Committee have given considerable thought to the reliability of questionnaires as methods of acquiring information. The method has manifest disadvantages, since the answers are bound to be very largely subjective. The wording of a

[1]Neither H.M. Inspectors nor the Ministry should be regarded as committed to any of the views expressed in this report.

question may also affect the kind of answer obtained. For example, the use of the word ' biology ' in a questionnaire addressed to a Primary School may suggest to a teacher the formal subject not taught in his school, whereas in fact, a good deal of biological work of a valuable sort may be in progress in the form of Health Education, Nature Study or Domestic Science. The Committee have nevertheless been compelled to use questionnaires, and have exercised the utmost care in the choice of the questions. They have also, whenever possible, left to those answering the questions full scope for the statement of individual problems and points of view. The Committee have also extended their enquiries to Teachers' Training Colleges, Field Study Centres, and University Departments of Education and of the Biological Sciences. The enquiries have covered the whole of England, Northern Ireland, Scotland and Wales.

The Functions of Biology in Education

Biology has a place in the general education of all people. The fundamental nutritional differences between animals and plants, the interdependence of organisms, the general picture of evolution and man's place in nature, the working of the human body including the biological basis of the human family are of the nature of necessary knowledge for all citizens, and none should leave school without this knowledge. Further, sound courses in General Science in Secondary Modern Schools require a substantial element of biology and if such courses include field work in connection both with biology and geography the students' interests are likely to be more easily stimulated. Here the function of biology is to broaden the scientific background of the citizen and to arouse in some at least a lifelong interest in Nature. At the Grammar School level biology becomes for the first time a separate subject, but its dependence on other sciences must never be forgotten. It must not be regarded as a substitute for either Physics or Chemistry. The tendency in some Girls' Schools to introduce Biology as the only science subject below the sixth form or as an easy substitute for Physics is to be deplored. On the other hand the science training of a schoolboy which neglects all biology is undesirable if his formal education is to cease when he leaves school.

Therefore the Committee believe that biology is a subject of intrinsic merit and educational value, and that it should not be included in a curriculum merely as incidental to such subjects as health education, pre-medical and pre-nursing scientific training, domestic subjects or sex education, although it has relations with all of these.

In so far as health education is concerned, the fact that this subject is compulsory in Training Colleges and finds an increasing place in school curricula is a stimulating and encouraging sign. It must be made clear, however, that at all levels, in Training Colleges no less than in Schools, Health Education should be based on biological knowledge and should be related to a sociological background, but of its own accord it should be taught against a well-designed matrix of practical demonstrations and laboratory work.

Since biological science is changing rapidly, and since the trends in school practice are varied and important, the Committee have felt that this report must be considered one of a series to be produced over the years.

Section I

The Position of Biology and Related Subjects in Primary Schools

While pupils in Primary Schools exhibit great diversity of ability almost all are possessed of that lively curiosity which is so essential for the proper development of informal biological teaching. However, the Committee was very conscious of the great variation in conditions from school to school particularly in relation to the number of pupils in each school and to the staff-pupil ratio of each school. Despite the effort which was made to secure evidence from all types of Primary School, it has been difficult to formulate generalisations on the data available.

It is clear that the majority of Primary Schools devote some periods to simple biological work which often consists of

observations of natural phenomena and the time so devoted appears to bear a reasonable ratio to other subjects at this stage. Effective biological teaching would appear to exist in many schools not professing to teach biology, the appropriate subject matter appearing in the curriculum under Nature Study, Natural History and Health Education. In co-educational schools Nature Study, Health Education and similar subjects are most often studied by joint classes and only occasionally by boys and girls separately.

Since the actual teaching is usually informal being based on specimens brought to school by the pupils it is subject to variation with the seasons of the year. The danger of wasteful repetition inherent in this method is realised by some schools where progressive and graded schemes of work are employed. Little evidence has been obtained of the purposeful linking of biological teaching with other subjects, such as geography, or of its evaluation in relation to Rural Science. Several schools report that B.B.C. broadcasts provide useful information and stimulate interest and that B.B.C. pamphlets are often valuable. In a similar sense the publications of the School Nature Study Union are helpful.

In contrast to such class-room activities, field work appears to occupy a very small proportion of the time allocated to biological studies. Nature Walks form a part of many schemes. Led by a keen, competent and observant teacher Nature Walks are most valuable, but a leader without personal knowledge and enthusiasm for field work can so easily transform a stimulating field lesson into mere physical recreation. Many schools keep rabbits, poultry, bees and other ' domestic ' animals, and school gardens, tended by the pupils themselves, provide a useful source of practical work. In only a few schools do out-of-school clubs exist in which pupils can develop hobbies having a biological bias. Some evidence was forthcoming of attempts to link school nature study with the outside world, thus some schools develop close ties with neighbouring farms while others visit museums, botanical gardens and zoological gardens. Difficulties of time-table organisation and of supervision of large classes of young children militate against many such visits, even where local opportunities do exist.

Existing and suitable biological text-books and readers are normally provided and are widely used, but the danger exists that reading from a text may be regarded as teaching biology. Evidence from many schools that the text-book is considered as a supplement to actual observations is encouraging, as is also the provision by some schools of a reference library to aid identification of specimens collected.

As may be expected, very few Primary Schools possess special accommodation for biology but it is disturbing to find that simple equipment for much-needed and valuable experimental work is also lacking. This may be due to lack of financial support or to the fact that teachers are not aware of the necessity for such work.

Only a few of the teachers responsible for biological teaching in Primary Schools have taken biology as a Training College subject ; the majority have no such special qualifications. Not many teachers appear to have taken advantage of part-time study leading to qualifications in relevant subjects such as natural history or horticulture.

The evidence available to the Committee leaves the impression that in too many instances less effective work in the biological field is undertaken in Primary Schools than is both possible and desirable. The child leaving school is too seldom inspired with that enthusiasm which might form the basis of life-long interest. Too much of the teaching is from books in the classroom, too little from first-hand observation in the field. This latter and desirable method of teaching requires smaller classes, relief from classroom teaching for planning, preparation and leading such field studies, and provision of training for the teachers themselves in field methods.

The Committee recommend that :

(1) Teachers should stress the relationship of biological studies to problems of everyday life and should so adjust their teaching as to make more clear than is now usual such interrelationships, and particularly the co-ordination of biological topics with such subjects as geography and hygiene.

(2) Outdoor work by pupils should be encouraged and wherever possible this should be of a quantitative character because experience has shown that simple measurements are well within the scope of the older Primary School pupils.
(3) Heads of schools should encourage suitable clubs such as Natural History Societies and Young Farmers' Clubs.
(4) Heads of schools should facilitate the work of their staffs by granting some relief for the preparation of practical studies and outdoor work.
(5) Those who teach biological subjects should be encouraged to attend suitable refresher courses to improve and extend their knowledge.
(6) Education Authorities should allow expenses to teachers attending such courses.

Section II

Biology in Secondary Modern and Secondary Technical Schools

Considerable variation in the teaching conditions in these schools occurs; in some there are modern well-equipped laboratories, in others there are no laboratories at all.

Biology is seldom a separate subject in the Modern School but is more frequently so in girls' schools than in boys' schools. The approach is often too academic and fails to stimulate interest in living things. While General Science is commonly taught in the Modern School, such courses do not always include some biology and the approach to General Science varies from school to school depending not a little on the background and interests, and hence the particular bias, of the teacher concerned. Since a biology teacher is a comparative rarity in the Modern School it is the biological content of General Science which often has least attention.

More numerous well-qualified science teachers are urgently required in Modern Schools. There seems little hope of improvement in the near future. Of the highly qualified science teachers in such schools, too many have specialised in Physics and Chemistry and have no biological training. This latter fact often discourages an essay into the biological field, resulting in undue emphasis on Physics and Chemistry. Sometimes a single biologist deals with the subject at all levels but this leads to an undesirable segregation of the branches of general science.

Evidence shows that the keeping of live-stock, school aquaria and school gardens, and visits to farms, zoological gardens and horticultural institutes is fairly general, but field courses in open country are too often neglected.

Adequate financial provision for the expenses of biological laboratories is a prime necessity all too frequently neglected even in schools having a generous 'books, stationery and equipment allowance.' It was disquieting to learn of initially well stocked and good laboratories becoming increasingly ineffective because of lack of funds to supply replacements of materials and consumable equipment. In Modern Schools, as in others, trained laboratory assistance is very rare.

Good text-books are generally available and many schools have good reference libraries, freely consulted.

It cannot be too strongly emphasised that the Modern School has a claim to the services of the expert teacher of biology, despite the present shortage of such teachers and despite the claims of Grammar Schools, but unless teaching conditions in Modern Schools are improved those in Grammar Schools too often prove more attractive to the better qualified teacher, who is free to exercise some choice. This choice is not only related to possibilities of special allowances but also to more generous provision of apparatus and materials.

While fully appreciating that the Modern School is a new venture, as yet in the developmental stage, the Committee received evidence that biological work in this type of school is often less effective and less satisfying than it ought to be. The few schools providing excellent biological courses are examples of what must be achieved more widely. The necessary improvements can only be achieved by co-operation between teachers and Local Education Authorities and County Education Officers.

Recommendations

The Committee recommend that :

(1) *All* courses in science in Secondary Modern and Technical Schools should include biology.
(2) Biology be taught to both boys and girls.
(3) Organised and quantitative field work should play a larger part in the work of most Secondary Modern Schools. Any keen naturalist on the school staff should be encouraged to contribute to the biology teaching.
(4) Adequate funds should be available to cover running costs of laboratories and to provide a petty cash account available to the biology teacher.
(5) Teachers of biology, particularly those having main qualifications in other subjects, should be encouraged to attend appropriate courses at Field Centres and should receive grants to cover expenses.

Section III

Biology in Secondary Grammar Schools

1. *The present position*

(a) Facilities

It is particularly in Secondary Grammar Schools that well-balanced blending of laboratory and field work is so essential to stimulate and maintain the interest of the pupils. Reports on all sides indicate that a major number of such schools have adequate biological equipment although not on the scale provided for Chemistry and Physics, but preparation rooms separate from laboratories should be provided. In smaller schools the practice of teaching biology in general science laboratories is undesirable, unless experimental work can be carried out elsewhere. Urban schools often lack facilities for keeping animals and studying growing plants and too often excellent facilities in rural areas go unused.

(b) Nature of Course

It is not the intention of the Committee to dwell on the nature of syllabuses but only to record comments of a general nature bearing on modern trends of biological teaching. The Committee noted the overwhelming complaint from many sources that biology teaching was too much confined to text-book studies with a consequent neglect of the living organism studied as an entity and a too common substitution of preserved specimens and morphological details for vital studies. Much of the blame for this state of affairs is said to lie with an External Examination system conducted mainly by Universities and demanding such a type of preparation. But the Universities counter such statements by insisting that Grammar School biology follows too closely their own 'Intermediate' courses and that often the teaching suffers from too frequent use of old familiar texts. Refresher courses for teachers dealing with new approaches to biological teaching are suggested while the Universities also note that some blame for the line Grammar School teaching has taken must be apportioned to the belief that 'type' teaching pays better dividends with the average student. It does not, however, stimulate a student's interest as does an experimental approach. Nor does it discover real intelligence. Cramming of factual knowledge, whether ancient or recent, leaves little time for the essential biology—the consideration of the living organism. It must be emphasised that many teachers desire to utilise living plants and animals in their courses but are discouraged from doing so by lack of adequate time for preparation and maintenance or by lack of adequate knowledge of how to provide and tend living organisms. This is related not only to the quality of the teachers but also to the absence of properly trained school laboratory assistants. The preparation for Biology laboratories, in contrast to Chemistry and Physics laboratories, is time consuming in the extreme. Individual experimentation will always be a problem in large and growing classes as will the high cost of materials, but much of the latter may be reduced by the use of simple and local resources—depending of course on the skill and imagination of the teacher.

(c) Field Work

Both in urban and rural schools too close attention to text-book studies results

in neglect of field work even to the degree that students are entirely ignorant of common plant and animal names, let alone possessing the knowledge of how to obtain these names for themselves. In a wider sense the study of living organisms in their environment leads to that proper appreciation of biology necessary in a world in which the day-to-day problems are biological rather than physical or chemical. The Committee regard such appreciation as an essential part of the education for citizenship and believe that it is greatly facilitated by adequate, organised field studies. Special attention to this aspect of our deliberations is given in Section IV.

2. *Certificate Examinations*

Consideration of examinations is based on data obtained under the old regulations. Comparison with more recent figures would be difficult.

(a) Trends in Numbers of Candidates

Since the British Association Report of 1928 very marked changes have taken place in the pattern of biology teaching. That Report dealt with the position between 1918 and 1927, and in the table below the statistics for the beginning and the end of that period are compared with the statistics for 1946 and 1950 in both School Certificate and Higher School Certificate grades.

Year	Number of candidates	Percentage candidates offering		
		Botany	Zoology	Biology
School Certificate[1]				
1918	33,563	25·2	1·3	3·5
1927	71,399	22·2	1·5	10·8
1946	100,160	2·4	Nil	27·5
1950	99,883	1·26	Nil	31·5
Higher School Certificate				
1918	1,303	6·2	0·46	0·54
1927	8,388	8·4	2·31	1·06
1946	23,063	6·8	6·9	10·6
1950	34,364	8·7	8·7	9·8

[1] Some 25 to 30 per cent. of the total candidates taking this examination in the 1946 to 1950 period offered General Science which includes some biology—perhaps to about one-third of the course.

Since the end of the 1914–1918 war the number of Secondary Grammar School pupils each year studying some form of biology at School Certificate level has increased about seven times for an increase in total candidates of only about three times. During this period the increased emphasis on general biology resulted in more balanced courses than those almost exclusively botanical (1918). At the Higher level increase in numbers of biology candidates has reached seventy times that of 1918.

More girls than boys study biology at Secondary Grammar School level and the following statistics are quoted from one Examining Board which examines some 10 per cent. of all candidates from England and Wales.

Ratio of girls to boys offering biological subjects in Certificate Examinations :—

	School Certificate	*Higher School Certificate*
1946	4·1	1·02
1947	4·0	1·05
1948	5·0	1·10
1949	3·8	0·91

The higher proportion of girls taking biology in School Certificate is partly due to the fact that few girls' schools teach Chemistry and Physics. Evidence exists that some headmistresses grudge time given to Science in girls' schools. Both trends tend to reduce the potential number of teachers in these subjects. There are several causes for the small proportion of boys studying biological subjects. The opportunities offered by industry to chemists and physicists tend to divert students to these sciences. Since small schools must economise in specialist teachers biology may be excluded or may be taught by a specialist in another subject. While biology is rather the ' orphan child ' of most boys' schools the increase in General Science in such schools would appear to provide some biological teaching, if the course is well balanced, in such schools offering this subject. Given even such a meagre introduction boys, on the average, tend to be more enthusiastic than girls.

At Higher School Certificate level the ratio of girls to boys taking biological subjects is approximately unity and the

increase in numbers of boys is partly due to those hoping to gain exemption from pre-medical University examinations by passing at the higher level. Many schools only offer biology in the sixth forms to intending medical students.

(b) Trends in Standards

It is almost impossible accurately to determine changes in the absolute standard of teaching and the average ability and performance of students. There seems little doubt that both the quality and the quantity of biology teachers has rapidly deteriorated. Meanwhile the population of Secondary Grammar Schools has increased. The evidence before the Committee indicates that these increased numbers have resulted in a dilution with mediocre students who must inevitably reduce the standards over the whole country, even though examination statistics give no evidence of this. During 1946 to 1950 the percentage awards in Public Examinations show no change and the Committee find it difficult to resist the conclusion that an arbitrary statistical adjustment is being made. If, as we believe, the average quality of Secondary Grammar School pupils is declining as numbers increase, this procedure means an automatic fall in examination standards. Some examining boards confirm the effect of dilution and the deterioration of the quality of teaching, stating that the best Higher School Certificate candidates show no change in quality while the performance of weaker candidates is worsening and that standards of practical work have definitely declined, resulting in an overall lowering of performance. A direct approach to one University Scholarship Board disclosed a considerable deterioration in the years 1949–1950. The Committee fully realises that this also may be highly subjective and yield a distorted evaluation of absolute standards of achievement. It urges that an attempt should be made to obtain estimates and maintain records of absolute standards of performance in all external school examinations in order that trends may be revealed, the more so as trends in both numbers and standards may be affected by the introduction of the General Certificate of Education. A later review, after the effects of such changes become established, would be of great importance.

3. *Pre-Medical Examinations*

No uniformity exists in University regulations for the statutory first medical examinations. Some permit a student to take their special *ad hoc* examination before residence or to qualify for exemption by virtue of appropriate passes in the General Certificate of Education (e.g. as in Cambridge). Others do not recognise school biological work and require the student to pass an elementary examination at the end of his first year (e.g. Scottish Universities). All possible gradations between these exist, for example, an external first M.B. examination may be taken but exemption cannot be claimed through the G.C.E., or exemption in biology may be obtained by passing in the G.C.E. sponsored by the University concerned, but not by passing in any other G.C.E. Thus the effect of pre-medical examinations on school biology varies with the precise requirements of the University with which a school is most closely connected and with the number of potential medical students it produces. At one extreme certain independent schools have sixth forms studying primarily for the London first M.B. ; at the other, many day schools are scarcely influenced since few of their pupils intend to read medicine and these cannot obtain exemption through G.C.E. passes at the University of their choice.

Biology was introduced into sixth-form work in many schools before, and just after, the 1914–18 war in order to meet the newly introduced external first M.B. of London and of Cambridge. Now the influence of pre-medical examinations presents two aspects. Firstly, no two pre-medical syllabuses have precisely the same content. Sufficiently annoying by itself, this state is aggravated where teachers must prepare candidates for two or more such examinations as well as for a G.C.E. examination and is worst where the same candidate must take a pre-medical examination as an entrance requirement and a scholarship examination based on an entirely different syllabus. Since all pre-medical examinations are an initial step towards a statutory registrable

medical qualification there seems no reason why they should not be interchangeable. Secondly, the syllabus of the G.C.E. and of the pre-medical courses appears reasonably similar in content but the teaching approach is vastly different. The former generally pays more attention to the living organism and seeks to lead the student to an all-round appreciation of biology; the latter has changed but little since the days when biology was equivalent to morphology and seems little more than an introduction to the technical terms required in the dissecting room. In this syllabus field work has no place—in our view a very grave omission. We hold the firm opinion that schools should be capable of providing adequate basic scientific training and that passes at advanced level in the G.C.E. in biology chemistry and physics should universally obtain exemption from a pre-medical examination. This provides a broader view of science than is possible in a medical school where the outlook is likely to be coloured by medical views and needs. It would prevent the boredom often inflicted on the student repeating work already done and it would allow medical schools to teach the more specialised science which they require. We do not believe that abolition of existing first M.B. examinations would be a bad thing for schools, because the claims of biology as a school subject do not rest solely on its value as a preliminary training for medical, nursing or any other profession.

4. *Other Entrance Examinations*

Influencing relatively few schools, University and College Entrance Scholarship examinations are mainly of concern because they require a different type of teaching. These examinations demand width of knowledge and an ability to think and to argue while G.C.E. examinations demand accurate detailed knowledge of a limited field. Experienced teachers resolve this difficulty and the main influence of scholarship examinations in maintaining a high standard of scholarship is wholly beneficial. Scholarship level papers under the new examination regulations may provide the remedy for this.

5. *General Review*

During the past thirty years development of biology in Secondary Grammar Schools has been influenced by the introduction of pre-medical examinations and by the recognition of the intrinsic educational value of the subject. The latter led to the establishment of biological classes at all levels in most schools. At upper levels the subject has been tied to the examination system with effects which are sometimes good, sometimes bad.

Where they exist, special laboratories for biology are often more modern than those for chemistry and physics, but they are too few in number. Very rarely is adequate, skilled laboratory assistance available to the biology teacher.

Some grammar schools are fortunate in possessing well-qualified teachers of biology, and even in the less fortunate schools there is usually a general leavening of biology. Against such benefits must be set a sombre record of recent, rapid, overall deterioration in teaching quality. This trend is alarming, the more so as Grammar School pupils are the intellectual cream of our country. Although fewer in numbers than pupils in other types of schools, they are destined to occupy positions of influence in industries, in the professions, and in administration and above all to provide the nation's future teachers.

After a struggle to establish biology in Secondary Grammar Schools lasting over a generation it would be deplorable if it were not allowed to develop, or even to continue, through lack of foresight at this critical time.

Failure to make our largely urban population aware of the world's extensive and grave biological problems is regarded as one of the greatest dangers which may arise from present-day science teaching in schools.

6. *Recommendations*

The Committee recommend that :—

1. *All* courses in science in Secondary Grammar Schools should include some biology.
2. Facilities for rearing live animals and for growing plants on school premises should be developed considerably.

3. There should be more refresher courses than at present for Grammar School biology teachers, not only in field studies, but also in all branches of the biological sciences.
4. There should be more contacts between School and University Biological Staffs than is now customary. To be fruitful contacts ought to be continuous and with full opportunity for the exchange of views. Contacts could perhaps be initiated and sustained through the medium of existing professional organisations.
5. There should be a more liberal supply of laboratory assistants than at present. (See also Section VI).
6. If any medical school exempts students from any part of the Statutory Pre-Medical Examination in Science, before admission, then passes at 'A' level in Physics, Chemistry and Biology of any recognised examining body should suffice for such exemption.
7. Statistical manipulation of marks which conceals true standards of achievement in public examinations makes it necessary to establish objective methods of comparing true standards from year to year.

Section IV

Field Work, Horticulture and Rural Science

1. Field Work; though Important is Neglected

A knowledge of plants and animals in their natural surroundings is an important part of biology. The obvious way to gain such knowledge is by observation in the field. We believe field work to be a fundamental concomitant of modern biology at all levels of study, both at school and university. All the evidence before us is remarkable for its emphatic unanimity of the widespread, even universal neglect of field work in biological teaching in schools. We have thought it necessary, therefore, to devote a separate section to the consideration of factors affecting field work.

2. Causes of Neglect and Conditions for Success in Field Work

From the Committee's attempts to discover the underlying causes of this widespread neglect of field work, the following general points emerge. Large classes of children, especially young children, are not easy to handle effectively out of doors. The work must be carefully planned beforehand, takes a good deal of time and requires first-hand knowledge of the objectives to be attained, as well as experience of certain techniques. Without previous training teachers fear to attempt work in the field; there is a disinclination to confess ignorance of the answers and thus to risk 'losing face' before pupils. Such an attitude, though mistaken, is quite understandable, and to overcome it requires moral courage. An additional deterrent is the lack of sympathy on the part of Heads of Schools, who do not understand the objectives of field work, are unappreciative of the fact that it cannot be confined to one lesson a week, but needs a half or a whole day and therefore necessitates modifications of the conventional school timetable. The conclusion has been reached that some method should be found of introducing Heads of Schools to the idea of field work, its essential benefits and the time it requires.

Similar reasons apply to the neglect of the indoor study of living organisms; in addition there is the frequent lack of a separate room for biology where aquaria and vivaria can be maintained without interference; and the lack of laboratory assistants to prepare practical material.

Though it is appreciated that examination syllabuses are not necessarily to be regarded as teaching syllabuses, the distinction in practice is a difficult one and, human nature and the pressure upon the school timetable being what they are, no subject which does not appear in an examination syllabus is likely to be given the attention it requires. The Committee regret that the syllabuses in the biological subjects of Examining Boards at the Ordinary Level seldom include sufficient references to field work. The difficulties of examining field work have been considered and are appreciated, but it is felt that they could be overcome. A further impetus could undoubtedly be given to field work in schools by suitable modification of existing examination syllabuses.

The indispensable pre-requisite for successful teaching of field work, is enthusiasm

in the teacher. If he or she is a keen naturalist, the enthusiasm is infectious and will spread rapidly. Where such enthusiasm, and a basic knowledge of field techniques exist, the deterrent factors mentioned above are overcome to a considerable extent. It is also clear that where field work is successfully undertaken in schools it is not a sixth-form activity only, but is encouraged throughout the school. It is also important not to attempt to cover too much ground at any stage and to integrate the work in the field with laboratory and class work. The common tendency to confine the year's field work to a week or two of intensive study is deplored. In Secondary Modern Schools, biological field work, where successfully undertaken, is linked to the general work on environmental studies, which is an encouraging feature of the curricula of these schools.

3. The Present Training in Field Work

It is apparent that Training Colleges are now alive to the necessity of stimulating ' interest ' rather than concentrating on book-knowledge and laboratory work, and courses are being developed with greater stress on field and practical work.

A changed attitude to field work in the Grammar Schools, particularly in their sixth-forms, is clearly the key to improving the situation, since they are the source from which both Universities and Training Colleges draw their students, and it is only from Universities that Grammar Schools and Training Colleges recruit their biological staffs. The evidence before the Committee demonstrates conclusively that biological work in the Grammar Schools is on the whole too formal and academic, field work is neglected and practical work is of poor quality.

From the considerable evidence supplied by numerous University Biological Departments the Committee note that no recent graduate should fail to have had at least the opportunity to be well grounded in field work, not only by means of many days spent in field studies, but also by supporting lectures and laboratory work. It is clear that this is not reflected in the teaching in the schools. There is small hope of immediate improvement of school biological teaching unless steps are taken to give the existing teachers adequate opportunities for widening their experience to include field work. In this connection the Committee has noted the encouraging results of holding Courses at Field Centres for practising teachers as well as for trainees; there is considerable evidence that this is a quick and effective way of arousing a changed attitude to field work on the part of already qualified teachers. Since attending Courses costs both time and money this calls for a far more generous policy on the part of Local Education Authorities towards grants-in-aid for field work than obtains at the moment.

A vicious circle is in operation : neglect of field work at Universities in the past has led to neglect in Training Colleges (who employ biological graduates on their staffs) and in Schools (who have graduates or Training College Diploma holders on their staffs). If members of staff neglect the subject, the great majority of pupils will naturally do so, with the result that Training Colleges and Universities then receive students whose interest in field work has not been aroused in earlier and formative years.

4. School Gardens

The school garden is now a feature of all types of schools and in the areas surveyed about 70 per cent. of the schools possessed gardens.

In Primary Schools the garden is used as an adjunct to the teaching of Nature Study. It has a value in preventing Nature Study from becoming formal and in allowing scope for the development of ' activity ' methods of teaching.

The school garden is of great importance in Secondary Modern Schools in rural areas, and in towns serving rural areas, where it is often the centre of the rural science studies. Most are used for vegetables and flowers, and in the larger gardens fruit is grown, and there is sometimes scope for individual plots and experiments.

The character of the teaching varies with the training, experience and enthusiasm of the teacher, with the apparatus and other facilities available and with the status of gardening in the curriculum. When the subject is integrated with

general or rural science a room is available for teaching. In the newer schools this is usually a laboratory with some facilities for experimental and demonstrational work. In older schools there is a room but often no laboratory equipment. Where the teacher of gardening is not also responsible in some degree for the science teaching there is often a garden shed for work in wet weather. In schools where the subject is poorly developed, and not regarded with much sympathy by the Head of School there is sometimes no shelter for wet-weather work and no facilities in school for demonstrations and experiments. Where the school garden is closely associated with the science teaching its educational status is generally maintained, but when gardening is taught in isolation by a craftsman without educational qualifications it becomes merely rule-of-thumb practice without any educational value. Moreover, there is a serious danger that repetitive work may absorb an undue proportion of time.

The status of gardening in the school affects the attitude of the parents and children to the subject. Owing to poor liaison between teachers and parents, the parents sometimes regard time spent in the garden as ' wasted ' because they do not intend their children to work on the land. This attitude is encouraged in some schools where only ' B ' forms do gardening.

The Secondary Technical Schools have been developed to give a more practical education than is given in Secondary Grammar Schools based on industrial and other local interests. In such schools gardening is usually linked with biology, which is taught only to certain sections of the students.

The school garden has a negligible place in the curriculum of most Secondary Grammar Schools. Here biology teaching tends to be formal and the link between laboratory and field is generally weak.

It seems a matter of some urgency that the position of the school garden be strengthened in Grammar Schools. The supply of teachers to all schools comes from the Grammar School pupils and unless the school garden is there shown as a focal point of Chemistry, Physics, Botany and Zoology and, in its artistic aspects as an outstanding influence in our cultural inheritance, it is unlikely that its full value can be realised in other branches of the educational system.

5. Teaching of School Gardening

Already some graduates in Horticulture and Agriculture enter the teaching profession and are finding places in Secondary Modern Schools. The raising of the status of the degrees of Horticulture and Agriculture to Honours level in some Universities should ensure that more graduates in these subjects find places in the Biology Departments of Secondary Grammar Schools and thus improve the educational status of the gardens in these schools. This should be a valuable step towards counteracting the extremely formal nature of present-day school biology, and work in the garden should prepare the way for diversified development of field work.

6. The Value of Field Work

In essence, the views of the Committee may be summarised under two headings.

(a) *The Essential Contribution of Field Work to Education*

Since organisms live in an environment with which they interact, any study of biology is incomplete which does not include first-hand experience of that interaction. Thus field work, and the different ways of studying the isolated organism in the laboratory are, in fact, complementary.

In field work the student has constant practice in critical and accurate observation and experience in summing up the relevance of a number of variables in a complex system. Such experience is seldom if ever provided by the physical sciences in schools. There is also some reason to believe that this experience has a bearing on the capacity to deal with problems of a similar complexity in other spheres. The Committee believe that field work engenders a flexibility of mind which is of great importance in tackling problems of a complex nature.

Education for the appreciation and enjoyment of the world around us should include the appreciation of nature as well as art. This appreciation and understanding can itself make a major contribution to certain aspects of education for

citizenship, namely, the preservation of the countryside and consideration for animals, since that which one appreciates and respects one will also wish to preserve.

(b) *Field Work in Relation to Examinations*

It is essential that teachers should cultivate a ' field outlook ' which involves learning by direct observation. Once acquired it permeates the entire biological work and answers in examinations are bound to reflect it. To help the teachers it is essential that they should themselves see examiners' reports, which do not always reach the actual teachers who prepare pupils for examinations.

The difficulties of assessing the candidates' abilities and training in field observation are very great. From the examiners' point of view it is suggested that candidates should be asked (perhaps by a rubric on the question paper) to give precise details of their field work, such as the time of year and the actual place of observation. The Committee note with regret that very few of the syllabuses at ' O ' and ' A ' levels include specific reference to field work. It is conspicuously absent from the syllabuses of the pre-medical examinations.

7. Recommendations

The Committee recommend that :

1. The co-operation of the School Inspectorate, both central and local, should be enlisted to urge upon all Heads of Schools the fundamental necessity of including field work in the curriculum at all levels of school biology teaching ; to see that it is given adequate time and that it is properly taught. Steps should be taken to familiarise Heads of Schools with the special problems associated with the teaching of biological field work, such as the time teachers need to survey the ground, the need to take pupils out at all times of the year, and the ways in which field study and laboratory work complement and supplement each other.
2. In Primary Schools, the widespread practice of relegating the teaching of Nature Study to teachers who have neither training nor interest in the work should be discontinued. Any member of staff with at least a predilection for the study of Natural History is to be preferred.
3. In Secondary Modern Schools advantage should be taken of the close interrelationship between geographical and natural history studies.
4. More opportunities should be provided for pupils in Secondary Grammar Schools to study horticulture. School gardening alone is considered to be of relatively poor educational value. It should be linked with courses in general science and/or biology.
5. The attention of those called upon to teach nature study or biology should be drawn to the basic short Courses in natural history provided at Field Centres.
6. Biology should rank as a subject for third-year Courses of study at Training Colleges, with attendance at residential Field Centres included as a vital part of the syllabus.
7. Teachers who already have some knowledge of field work should be encouraged to attend refresher courses at Field Centres from time to time.
8. The attention of teachers is drawn to the Certificate of Proficiency in Natural History of the Extra-Mural Department of the University of London. This is designed to meet the special needs of those teaching biology in schools. A similar syllabus might well form the essential part of the third-year Course in Biology for Training College Students advocated in Recommendation 6 above.
9. Wherever possible practical field work should be an integral part of the curriculum throughout the school; sixth forms (especially of schools in urban areas) should attend at least one week's course at a residential Field Centre during the year.
10. The co-operation of the various Examining Boards should be enlisted to ensure that specific reference to field work is made in syllabuses at both the ' O ' and ' A ' level. The Cambridge Local Examination syndicate has (March 1953) formulated a scheme whereby the candidates may

receive credit in the General Certificate of Education for individual or group field work in biology.

11. All Local Education Authorities should aid students of biology—both teachers and pupils—who require financial help to attend residential courses in field work.

Section V

School Biological Staffs

1. The Supply of Teaching Staffs

(a) *Secondary Modern Schools*

Little accurate evidence exists of the numbers and qualifications of teachers of biological subjects in Secondary Modern Schools. From the information available it is clear that there is a grave shortage of qualified teachers in these subjects, one estimate stating that 30 per cent. of such schools had no trained science teachers.

(b) *Secondary Grammar Schools*

The Hankey Report has received wide publicity. From another source covering 777 schools having 2,414 vacancies in 1948–1949 the following distribution of appointments was noted :

Subject	*Percentage of Posts unfilled*	*Percentage of Posts filled unsatisfactorily*
Biology	40	22
Chemistry	26	19
General Science	22	26
Physics	19	24
Mathematics	16	29
Modern Languages	7	12
Classics	7	13
History	4	10

In this year only 38 per cent. of vacancies in biology were filled satisfactorily. This demonstrates the outstandingly adverse position in respect of the supply of biology teachers. The same source provides evidence that the quality of the staff is also declining.

	1939	*1949*	*Percentage change*
Number of pupils in schools surveyed	244,196	300,445	23
Number of Sixth Form pupils	22,018	36,949	67
Number of Staff with 1st Class Honours	2,200	2,127	−3
Number of Staff with 2nd Class Honours	4,760	5,997	25·9
Number of Staff with other qualifications	5,107	6,630	29

Thus while pupils have increased by 23 per cent. over the ten years period, numbers of teachers have increased by 22 per cent. Pupils in the sixth forms have increased by more than 50 per cent. and, assuming the usual teacher/pupil ratio for such forms as twice that for the rest of the school, a staff increase of 26·4 per cent. should have been effected. But actual staff increases have involved appointment of second-class graduates and others with even less qualifications. Further, first-class graduates not only fail to enter schools but also some already in schools are leaving for other employment. To maintain the 1939 ratio of first-class graduates to pupils a total of 2,770 graduates would be required. The actual figures are 643 below this, representing a decline in quality of this order (23 per cent. of the total) in ten years. These figures include all subjects and the position in biology is infinitely more grave than is suggested by the figures quoted.

From this same source the methods of dealing with staff shortages are set out as follows :—

	Percentage
Modification of courses, e.g. combining forms and reducing time given to subject	13·5
Sending forms to other institutions	18·6
Using part-time teachers	19
Using teachers unqualified in the subject	32·6
Abandoning the subject	14·9
Private study	1·4

If the data are representative of the whole country it can be calculated that about fifteen Grammar Schools each year are dropping biology, while almost fifty more schools are employing teachers having no University biological training.

(c) *The Hankey Report*

This report indicates that the greatest demand for graduate biologists between 1950 and 1954 will be as teachers of biology in schools. It is estimated that 1,200 will be required for Secondary Grammar Schools which agrees with the number arrived at by the Committee from other evidence. The Report estimates that by 1954 a surplus of biology graduates may be expected, even after teaching requirements have been met. This Committee cannot accept this estimate and questions the validity of the

various criteria upon which it is based. But, even allowing that such an excess is imminent it is clear that the majority of biology graduates at the moment are reluctant to teach in schools and there seems small hope that, if an excess of graduates materialises, it will have an appreciable effect on the recruitment of biology teachers. Apart from this there is the much greater problem of staffing the Secondary Modern School. If the Hankey Report succeeds in inculcating the idea of a surplus of trained biologists, this may have a disastrous effect at the source by reducing the flow of candidates in biology and by tending to remove the subject from the school curriculum. The Committee are entirely convinced that biology occupies a place with the three 'Rs' as an essential element of the education of future citizens and they believe the supply of trained biologists for other requirements is incidental to this one major requirement.

2. Training of Biology Teachers in Teachers' Training Colleges

In the past few years about 10 per cent. of the entrants in such Colleges have studied some form of biology at school, usually in a general science course and not as straightforward biology. Only about a half of these entrants possessed a Higher School Certificate in a biological subject and most of these had taken it at subsidiary level. The remaining entrants had usually studied either School Certificate biology or general science, but in some Colleges a considerable number of entrants had no previous experience of biology, the majority of these being men students. The Colleges deplore the average low quality of the biological experience of the entrants, their lack of innate interest and their failure to grasp the social implications of the subject. This is perhaps a reflection of the text-book teaching at school, of the absence of contact with living plants and animals and of the lack of early contact with natural history. Such a background scarcely disposes a student to proceed with biology and many who do regard the subject as difficult because they are expected suddenly to develop the ability to learn by personal observation and not from books; an adjustment not easily or quickly achieved. In these Colleges many of the students who become good biologists have had no previous contact with the subject and thus benefit from the appeal of a fresh discipline.

The majority of Training Colleges report a marked decline in the quality of biology entrants and attribute this to the increased demands of industry for Chemists and Physicists, a demand which offers better financial rewards, and which undoubtedly influences the science subjects in school curricula.

The Colleges recognise that real interest is the primary requirement of a sound biology teacher and the College courses stress experimental and field studies encouraging students to make simple pieces of apparatus and to visit and study at Field Centres. But the two-year period of training is recognised as being insufficient for intending teachers of biology since much of their College time is devoted to essential school practice and some Colleges are recommending the extension of the course to three years. With this the Committee are in complete agreement.

Staff shortages, particularly in the technical or laboratory assistant grade, are as great here as in schools. Laboratory assistance is absolutely essential and deficiencies should be rectified as soon as possible.

3. Training of Biology Teachers in Universities

The Committee received a unanimously negative answer from the biological and allied departments of University institutions of Great Britain to the question whether special attention was given to the requirements of intending biology teachers. A few departments admitted advising such students not to specialise too narrowly and to take a general or a general Honours rather than a special Honours course. Often advice is given on the subject combinations, particularly to study Botany and Zoology together to as high a level as possible. Universities are fully conscious of the importance of field work in the training of biologists and special provision is made for this in each year of study.

A very high proportion of intending teachers enter University Departments of

Education or Teachers' Training Colleges after graduation to train in the principles and methods of teaching and to obtain pre-employment teaching practice. There is some evidence that students find this teaching practice the most effective training in method and that they owe much to the permanent staff of the school to which they are attached. Several sources report that the 'special method' courses might be greatly improved by including precise and definite information of the daily requirements and techniques of the biology teacher. This would allow the student to practise them for himself rather than as at present both learn them and try to practise them during his period in school.

4. Laboratory Assistants

Frequent reference has been made in this report to the necessity for laboratory assistants in Schools and Training Colleges, therefore the Committee investigated the supply, the conditions of service and the training of technical assistants.

(a) *The Supply*

All the Local Education Authorities in Great Britain and Northern Ireland (192) were invited to provide information of the numbers of laboratory assistants in their employment. Independent Schools and Technical Colleges were excluded. Six hundred and sixty-five laboratory assistants are employed in all types of science laboratories by the 118 authorities who replied. While the average number of assistants employed by each authority is 5·6 considerable variation occurs and more assistants are employed in England than elsewhere. When the London averages are included urban areas are slightly better served than rural areas (10·1 as against 9·3) ; when the London averages are excluded the reverse is true (2·7 as against 6·6). This suggests that recruitment is easier in rural areas, perhaps due to lack of industrial competition. In certain counties no assistants are employed.

Such employment is mainly in Secondary Grammar Schools. While whole-time assistants in biological laboratories were scarcely expected, only two such were recorded. Part-time assistance appears to be recruited from :—

(a) Senior pupils of the school (paid).

(b) Former pupils gaining experience before further education.

(c) School caretakers.

(b) *The Remuneration*

Full-time assistants are paid within the scale £120 to £130 per annum at 16 years, to £350 at 25 to 30 years, but as the ages of assistants vary from 16 to 21 years, the pay within the scale is low and some authorities terminate the employment at age 19 or 21. Six authorities drew specific attention to the difficulty of filling vacancies in urban areas.

(c) *Training*

Generally assistants have no biological training other than that acquired in general education, but a few attend courses at local Technical Colleges or engage in spare-time study for the G.C.E. One authority has a training scheme.

5. Recommendations

The Committee recommend that :—

1. University departments should encourage recruitment by stressing the national importance of teaching biology and the wide influence such teaching has upon the community.
2. Heads of Schools and Universities should encourage teachers to conduct appropriate research work. The Committee fully appreciate the difficulties of time and space which the customary type of school organisation pose, but they are convinced that serious efforts to introduce facilities for investigational work by the teachers would go a very long way to making posts more attractive and so improve recruitment both as to numbers and as to standard. Also such facilities would stimulate deeper interest in the methods of biological teaching.
3. Adequate numbers of laboratory assistants should be provided, that training schemes for these assistants should be developed and that assistants should be encouraged to secure qualifications as a result of training which enable these positions to rank as careers and not as 'dead end' posts. The use of pupils as laboratory assistants is considered bad in principle, likely to derange their general education and should be discontinued.

Section VI

Methods of Teaching Biology

1. Purpose of the Section

While it has been recognised from the beginning that adequate treatment of the methods of teaching biology lies outside the scope of the Committee's enquiry and involves the consideration of many and varied factors, it has nevertheless been necessary to consider certain aspects of the problem of teaching methods not only because of weaknesses discovered during our collection of evidence but also because of our conception of the nature and place of biology in schools as set out at the beginning of the Report.

2. General Remarks

The problems to be discussed cannot be solved by the individual teacher alone; they require as well the help, sympathy and practical assistance of the Head of the School, the Education Administrators and the Education Committees. Only the Head of the School can ensure that a fair proportion of the finances is disbursed for biological studies, that specimens and apparatus left in common class-rooms is undisturbed, that clubs and study groups are promoted, that teachers are encouraged and assisted to attend refresher courses, and that vital integration of related subjects within the school timetable is effected. Administrators can ensure that teachers have reasonable leave of absence and are given financial assistance to attend refresher courses.

3. Weaknesses in Current Practice

Evidence presented to the Committee disclosed two main defects in current teaching practice: neglect of field work and failure to utilise simple and easily obtained materials.

(a) *Neglect of Field Work*

We are acutely aware of the difficulty which faces teachers of all but the more advanced classes in smaller Grammar Schools, of providing worthwhile instruction to large classes in the field. Tuition is well-nigh impossible and large numbers defeat the ends of true field work by preventing quiet observation and by removing or destroying plant material.

Effective field work should be related to the rest of the syllabus of study and should be pursued throughout the year by periodic visits to selected localities. In this rural schools have an advantage over urban schools, but in both the support, encouragement and assistance of the Head of the School is a primary requisite for success. We advance the following suggestions with particular reference to the urban schools.

1. *Groundwork.* Stimulate interest in a field project before commencement.
2. *Aims.* Simple, limited and relevant objectives should be set and should be discussed beforehand with the class. A prior visit by the teacher to the study area is helpful.
3. *Competition.* Group study and competition is frequently useful.
4. *Records.* Clear, simple and accurate observations recorded at the time are more valuable than later impressions written in class.
5. *Discussion.* Class-room and laboratory examination and discussion of field results are essential and form a natural corollary of outdoor studies. Theses should be coupled with suggestions for later investigations.
6. *Identifications.* The teacher should not be deterred by his ignorance of particular specimens. It is often of mutual advantage to pupil and teacher to learn together.
7. *Correlations.* Accurate observations may with advantage be correlated with other local studies but diffuse generalisations are dangerous and must be discouraged.
8. *Measurements.* The essence of modern field work lies in the insistence on simple quantitative determinations such as numbers of individuals in populations, size distributions and so on.
9. *Equipment.* Tape measures, rulers, jam-jars, wooden stakes, string and a modest collection of reference works are the simple requirements for initiating field studies.

(b) *Materials*

Absence of specific and uncommon types of plants and animals does not militate against sound biology teaching.

Local plants and animals—even in towns—provide a sufficient range of types for study but their full exploitation depends upon the interest and curiosity of the teacher and on his ability for continuous personal study. Apparatus need not be elaborate and a simple lens properly used can replace compound miscroscopes in all but sixth forms. Microprojectors are helpful with large classes.

4. Special Problems of Secondary Schools

(a) *Secondary Modern Schools*

The following suggestions, based on our introductory remarks on the function of biology, may be of value to the biology teachers in Secondary Modern Schools.

(1) A definite sequence should underlie each lesson or course.
   (a) Start with a biological phenomenon known to the children from their daily life.
   (b) By the use of suitable living material and direct observations or experiments establish firm first-hand knowledge of the topic.
   (c) Indicate its social implications, especially where field work has been involved.

(2) Neither the scientific nor the practical aspects of a topic should be allowed to obscure the appreciation of beauty or the desire to become acquainted with plants or animals for their own sake.

(3) Interesting practical work requires that the teacher should be a capable organiser well versed in specialised laboratory techniques. At this point the efficient laboratory assistant becomes important as a member of a team. Only so can a wide and interesting range of work be covered.

(4) The social relevance of laboratory and field biology probably escapes many pupils. Such features as the dependence of plants upon sunlight and a fertile soil, of animals upon plants and as the meaning of competition for food supplies, go far towards an appreciation of some of the vital problems in the world to-day. No teacher can render a more important social service than helping the pupil to realise the contribution adequate scientific research can make to such vital problems.

(b) *Secondary Grammar Schools*

The following aspects refer specifically to these schools :—

(1) Influence of the external examination system.
(2) Work is often out of date.

(1) In view of what has been said in Section III all that needs consideration here is the effect of examinations on teaching methods. A set syllabus tends to prevent unbalanced development of the subject, but it also prevents the following of interesting side lines occurring in material under study and of interest to pupils. While the sound answer to many an intelligent question is either ' look and see ' or ' experiment and find out ' the pressure of time, the ground to be covered, and the needs of several different syllabuses may combine to frustrate the educational aspirations of a teacher. Here, no guiding principles can be advanced as have been attempted in relation to such topics as field work. If a teacher believes that the purpose of school biology is to provide a training for a few professional research scientists, his emphasis will be very different from that of a teacher who believes that his primary mission is to give future citizens some biological knowledge on which to base their evaluation of the problems of everyday life. The better teacher will consider and cater for both of these aspects.

The contribution of the biologist is both aesthetic and practical, and it is vital that biology be recognised as the equal of any subject in its basic scholarly values and its educational disciplines.

(2) The charge that Grammar School biology is often out of date may be due to a misconception of its functions. In the training of a scientist the current aspect of research is significant. No teacher can remain familiar with advances in all branches of a vast group of subjects and can only do his best in a limited field through contact with professional societies and their journals. Additional refresher courses are urgently required. The Committee suggests that Heads of Schools should do all in their power to help their teachers to maintain a live interest in the

advances in their subject by encouraging their staffs to attend meetings and courses, even through timetable rearrangements. Such contact with new knowledge is necessary if teaching is to be regarded as a learned profession. But such new knowledge must be carefully screened in presenting it to the pupils because basic principles are an essential part of education and must not be omitted in favour of new and interesting data. Rather, the new knowledge gained should revitalise the method of presenting basic principles.

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